


MASTER PROGRAM IN SYSTEM DYNAMICS

PROGRAMEVALUATION AND RE-ACCREDITATION
FALL 2020

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1 INTRODUCTION: THE SYSTEM DYNAMICS METHOD AND MASTER PROGRAM

Large organizations such as the UN, EU, and OECD are now asking for systems thinking to come to grips with increasingly complex problems evolving over time. System Dynamics provides stringent methods for systems thinking and for interdisciplinary research.

System Dynamics is the study of complex, dynamic systems by means of computer-based modeling and simulation. These systems are ubiquitous and transboundary, - they transcend social sectors and scientific disciplines. The structure of such systems encompasses non-linearly coupled causal feedback loops that are characterized by time consuming processes (delays) and stochasticity. Such structures produce dynamic developments over time (including chaos) that do not easily lend themselves to interpretation or, even less so, to management. Such studies are typically threefold:

1. We need to understand the dynamic development that complex systems exhibit over time. Specifically, we study problem developments, and seek to understand the nature and the structural origin of such dynamics.
2. We need to analyze strategies and policy designs to reduce problems and ensure favorable developments. We test policies in the very same models that we use to analyze the origin of problematic dynamics.
3. We need to disseminate systems insights among students, stakeholders, strategy developers, policy designers, decision makers, and the public at large, so as to promote systems understanding and facilitate good systems governance. We do so, making use of digital learning technologies.

Our research and education focus on theories, methods, techniques, and tools aimed at addressing these needs. This includes e.g.;

1. data collection, modeling, statistical parametric and non-parametric estimation and interpretation, surveys and conjoint analyses, synthetic data analysis, machine learning, model-based decision-lab experimentation, “big-data”-based model identification, group model building, community-based modeling, Monte-Carlo and sensitivity analysis, feedback loops dominance analysis (such as gain, eigenvalue, pathway participation, and link and loop score analyses), agent-based modeling;
2. dynamic control analysis, policy optimization in stochastic domains, and stakeholder involvement; and
3. multi-user interactive learning environment technologies (ILEs embedded in MOOCs), - originating from learning-theory, stock and flow diagrams, graphics, animations, gaming, and learning analytics.

The System Dynamics program at the University of Bergen is unique in the sense that there exist no corresponding combination of Master´s and PhD education worldwide.

2 REQUIREMENTS FOR THE STUDY PROGRAM IN UIB'S SYSTEM FOR QUALITY ASSURANCE IN EDUCATION

2.1 Admission requirements and admission numbers

The study program in System Dynamics at the University of Bergen consists of two components, the local Masters Program in System Dynamics that has been in operation since 1995 and the European Masters in System Dynamics (EMSD), offered in collaboration with 3 additional European institutions, a program that has existed since 2009. This report predominantly addresses the local program.

However, since the students in the EMSD program, while studying in Bergen, are fully integrated in our student body, it is, in many cases, difficult to distinguish the two. This is true, e.g. when assessing resource allocation, utilization and productivity. On the other hand, we recognize that the admission process and the characteristics of the students, their grades, their financing opportunities etc. are different, and we may, consequently, utilize those differences to contrast the two student groups so as to explain the dynamics of the local program. In what follows, we explicitly state when we refer to, contrast with or incorporate assessments of the EMSD program. When nothing else is stated, this report concerns the Masters Program in System Dynamics located in its entirety at the University of Bergen.

When assessing the System Dynamics program, is important to keep in mind that the program has, from its very start, been offered in English and to a target group of international students. Although the program was opened to Norwegian students in 2000, student recruitment has never been underpinned by a bachelor program in the field of System Dynamics. The admission requirement is a bachelor education in social sciences, including management, and natural sciences, including engineering.

There is a large number of students applying to the Masters program in System Dynamics as compared to the study places allocated. Referring to the admission years 2016-2020, Table 1 (drawn from Tableau[1]) shows the number of study places made available, applicants indicating System Dynamics as their first priority, offers given, offers accepted and the number of students who attended at the start of their studies (registered).

[1] https://dbh.nsd.uib.no/statistikk/kategori_studenter.action;jsessionid=6LXEx5Ekt7lB4DWacwzWyJr+.undefined

Table 1: Study places (studieplasser), applications with SD as first priority (1. prioritet), offered study places (fått tilbud), accepted study places (svart ja) and registered students (registrert) (data source: Tableau)

Søkning og opptak

Studieprogram	Årstall	Termin	Studieplasser	1.prioritet	1. pri søker per studieplass	Fått tilbud	Svart ja	Registrert	Andel registrert av tilbud
MASV-SYSDY	2016	HØST		129		36	20	17	47,2%
Masterprogram	2017	HØST		137		65	34	24	36,9%
i	2018	HØST	25	161	6,4	58	28	19	32,8%
Systemdynamik.	2019	HØST	23	158	6,9	60	33	28	51,9%
-	2020	HØST	28	154	5,5	93	70	35	49,3%

Note that the percentage calculation for 2020 and 2019 in Tableau is not correct:

- 2019: 28 (registrert) is 47% of 60 (fått tilbud)
- 2020: 35 (registrert) is 38% of 93 (fått tilbud).

The table does not describe the actual situation in 2020 either. Due to the Covid-19 situation, 24 out of the 70 students who accept the study place (svart ja) accepted deferred admission until fall 2021. This leaves us with 46 student that were supposed to start fall 2020. 35 of them did in fact start, which is 76% of 46.

Supplementary figures from NSD (Table 2) show that we also have a high number of applicants who have System Dynamics as their second or (less frequently) third choice.

Table 2: Applicants for MASV-SYSDY 2016-2020 (data source: NSD)

year	**2016**	**2017**	**2018**	**2019**	**2020**
All applicants	199	233	252	240	239
Applicants with SD as first priority	129	137	161	158	154

It is interesting to contrast these numbers with the ones characterizing the EMSD program. In that program, the ratio between admission and applicants has been around 13%, a considerably narrower admission margin, - causing the students to be more qualified in the fields of their bachelor education.

Measures to increase recruitment and/or quality of admitted students to the program:

- SIU / DIKU exchange programs with NaUKMA and the National University of Lviv in Ukraine as well as the University of North Dakota, USA: As part of their masters and PhD education, students spend the fall semester in Bergen and participate in the same courses as the first-year students of our master program (plus some special topics courses, cf. Table 6). This allows the exchange students to learn the basics of the System Dynamics method and integrate these competencies in their further economics (Ukraine) and public health (North Dakota) studies. The benefit for the System Dynamics master students lies in the exposure, from day one in their studies, to important fields of application of the System Dynamics method.
- The University of Bergen has, since 2009, been member of a university consortium offering the European Masters Program in System Dynamics (EMSD). For 9 years, 2009 – 2018, this program was rated among the relatively few pan-European masters programs included in the Erasmus Mundus program. The program received excellent reviews by the EU Commission and was

renewed for 4 years after its first 5 years of operation. The students in this program were selected among up to 200 applicants and performed disproportionately well. All students in this program received their foundation in System Dynamics at the University of Bergen and a disproportionately large fraction returned to Bergen for their thesis work. The partner universities have recently taken the initiative for the University of Bergen to coordinate the application for continued Erasmus Mundus funding. The System Dynamics Group is currently coordinating this work. We expect this to result in the recruitment of a minimum of 20 excellent students in the course of the next 4 years.

- Incoming exchange students (UTV-INN): Every year we have a considerable number of incoming students nominated on UiB exchange agreements (e.g. bilateral, Erasmus +, Nordpluss, Eurasia).
- Recruitment of guest students at masters and PhD level for selected courses of the master program in System Dynamics: Every year, we have a varying number of students who find that they do not have sufficient knowledge and skills in System Dynamics and its application to complete their master or PhD studies in other institutions and thus prefer to take at least parts of our master program. In some cases, we have even had guest students who ended up completing the entire master program in Bergen.
- GEO-SD330/660 “Natural Resources Management”: This is Norway's first online distance learning course similar to a Massive Open Online Course (MOOC) that is offered both as part of our master program and as a continued education course. This course has recruited students to both our master and PhD programs. It has also lead to a research project in collaboration with UNEP. Based on the positive feedback accumulated over the last years, this distance learning course has inspired us to pursue a fully online master program. GEO-SD302 “Fundamentals of Dynamic Social Systems” is now ready to be offered as a distance learning course. As a result of our Erasmus+ project “Systems analysis MOOCs for sustainability transformation”, more courses will be turned into distance learning courses.
- This process has been accelerated by the Covid-19 pandemic, which forced us to go fully digital on short notice.
- In July 2020, the System Dynamics Group at the University of Bergen hosted the 2020 International Conference of the System Dynamics Society. While the conference had originally be planned to take place physically in Bergen, going online allowed us to attract almost twice as many conference participants as originally budgeted. This increase in participation is another indication that individual online courses and an entire online master program will allow us to increase the reach of our education. As a follow-up, we have been invited to join Acadeum, a US based network of colleges and universities committed to sharing their best online courses so as to improve student performance. This will extend our current plans to exchange online courses among the partners in our Erasmus+ project.
- To give applying students a better idea about the skills required, we have offered an online readiness test. We plan to extend this with a pre-application crash course in the rather limited, however very important, basic skills in mathematics required to succeed. By discouraging some students from applying and preparing those who do apply, we believe we will reduce the initial dropout rate.
- Currently, the Faculty of Social Sciences negotiates an exchange agreement with Université Paris 1 Panthéon-Sorbonne, School of Management. The intention is for students in the “Masters M2 Management des Systèmes d'information et de Connaissance et Management of Information and Knowledge Systems” to obtain a double degree, including a M Phil degree in System Dynamics. We expect an initial number of 12 students to enroll in this program in 2021. The program is a novelty

in that it is funded by a consortium of industry partners and combines academic studies with secondments among these partners where the students undertake empirical research.

2.2 IMPLEMENTATION, DROPOUT AND CANDIDATE PRODUCTION

Table 3 shows throughput figures for students during the period 2014-2020.

Table 3: Registered vs. graduated students for starting years 2014-2018 (data source: Tableau)

			Semester number							
Start year		Grand Total	1	2	3	4	5	6	7	8
2014	Active	18	18	15	13	13	8	4	1	2
	Accumulated graduations	8	0	1	1	3	6	8	8	8
	% graduated	44.44%	0.00%	5.56%	5.56%	16.67%	33.33%	44.44%	44.44%	44.44%
2015	Active	35	35	29	27	26	17	9	4	4
	Accumulated graduations	19	0	0	0	7	14	18	18	19
	% graduated	54.29%	0.00%	0.00%	0.00%	20.00%	40.00%	51.43%	51.43%	54.29%
2016	Active	18	17	14	11	10	3	3	2	1
	Accumulated graduations	8	0	1	1	5	7	7	7	8
	% graduated	44.44%	0.00%	5.56%	5.56%	27.78%	38.89%	38.89%	38.89%	44.44%
2017	Active	23	23	19	16	16	5	5	3	
	Accumulated graduations	11	0	0	0	9	9	11	11	11
	% graduated	47.83%	0.00%	0.00%	0.00%	39.13%	39.13%	47.83%		
2018	Active	18	18	16	13	12	2			
	Accumulated graduations	10	0	0	0	10	10	10	10	10
	% graduated	55.56%	0.00%	0.00%	0.00%	55.56%				

There is, apparently, a significant discrepancy between the number of students who start and those who complete their education. A mere 45 – 55% of the students admitted were able to complete their studies successfully. Our assessment is as follows;

The System Dynamics program is a *graduate* program that demands that the students, most of whom are unfamiliar with System Dynamics because there exists no bachelor education in the discipline, follow a very steep learning curve for which many students are unprepared: We have opted for the admission of a wide variety of students, in terms of;

- Disciplinary background (see 2.1) at bachelor / masters level;
- Grade (min C);
- Nationality / institution of origin;
- Gender.

The rationale is that we want students from many walks of life, which makes up a vibrant student community that is reported to be highly appreciated by our students. Moreover, we find it hard to predict who will be well suited for our education. We do offer a web-based readiness test for the students to take on a voluntary basis, but do not offer a formal admission test. Finally, we have accepted the grade C as a minimum, the skills behind which vary significantly from institution to institution across the globe. In short, we admit a wide variety of students and thus use the studies themselves for us to assess the quality of the work the students deliver and for the students to assess their performance and suitability in the context of this program. When some students register as active students in spite of a low performance and an intent not to complete their education, that may be caused by alternative motives such as the desire to remain in Norway for part time work. This may be the reason why we see some students register well beyond the time when they, in reality, have terminated their full-time studies. To remedy this drop-off, we may rely on considerably stricter admission criteria or encourage more well-qualified students to apply in large numbers. *This conclusion emerges from a comparison with our reference program, the EMSD where, the drop-out altogether has been somewhere between 1 and 2% for all 9 cohorts (a drop-out entirely caused by personal extra-curricular challenges).*

The high grades that EMSD students, overall, obtain, indicate that the quality of our education is sufficient and well-matched with demanding project requirements and exams.

Referring to the completion fractions of cohorts admitted 2017 - 2018, 45 and 55 % of the students admitted, completed their education, - most of them on time or one semester delayed:

Of the students who *did* complete their studies;

- 2018 Cohort: 60 % completed their studies on time and 100% by the 5th semester.
- 2017 Cohort: 82 % completed their studies on time.

With regard to the students in cohorts 2015 – 2016 that *did* complete their studies, *special circumstances prevailed* and the results may be summarized as follows;

- 2015 Cohort: 37% completed on time, 72 % by the 5th semester and 95% by the 6th semester.
- 2016 Cohort: 37.5% completed on time, 37.5% by the 5^{th} semester and 100% by the 6^{th} semester.

The special circumstances affecting the cohort 2016, was a significant work overload on the part of the faculty members, a significant graduation of additional EMSD candidates, a leave of absence due to a long-term sick leave and subsequent sabbatical, and a change of staff. For a group of 3 persons, this load and these disruptions caused us to rely on external supervisors for a majority of the master students. These supervisors contributed during the student´s thesis work. Inevitably, that caused delays, albeit no quality reduction, in the student´s performances.

In summary, except for the dropout-rates addressed above, the student cohorts have predominantly performed to our satisfaction. Personal circumstances, such as a demanding financial situation, are presumably the main cause of the 1 semester delay that we experience. We currently have urges the students to pay attention to the deadlines and expect an improvement in that regard as of the 2019 cohort.

As illustrated below, the trend is moving towards a full compliance with our goal, i.e., to retain all students, at least as of the second semester. During the spring of 2020, *all* of the students enrolled in the program completed all 30 credits required for that semester.

In terms of credit and candidate production, we refer to publications by the Faculty of Social Sciences as well as Tableau: As portrayed in Table 4, the Faculty of Social Sciences reports, in the white paper "Structure and Cooperation" 2020, that the masters program in System Dynamics is the one at the Faculty that educates the largest average number of students per course (of which there are 9 per year, -i.e. in addition to the special topics courses and the master thesis courses):

Table 4: Average size (i.e. number of graduating students) of program components (subjects / courses), soring / fall 2019, master level

Course code	Number of students passing
MAN	9
SANT	10
UJO	10
MIX	10
SOS	10
MEVI	12
GEO	12
ECON	17
INFO	19
AORG	19
SAMPOL	19
GEO-SD	**21**
Average	**15**

Norwegian master program titles: MAN: Manusutvikling for serier, SANT: Sosialantropologi, UJO: Undersøkende journalistikk, MIX: Medie- og interaksjonsdesign, SOS: Sosiologi, MEVI: Medievitenskap, GEO: Geografi, ECON: Samfunnsøkonomi, INFO: Informasjonsvitenskap, AORG: Administrasjon og organisasjonsvitenskap, SAMPOL: Sammenliknende politikk, **GEO-SD: Systemdynamikk**.

More specifically, the students per course is distributed as follows:

- GEO-SD302: 48
- GEO-SD303: 18
- GEO-SD304: 44
- GEO-SD308: 22
- GEO-SD309: 14
- GEO-SD310: 13
- GEO-SD321: 25
- GEO-SD322 :13
- GEO-SD323: 3
- GEO-SD325: 14
- GEO-SD330: 19

Ignoring the two special topics courses that are not parts of the standard curriculum, GEO-SD 322 and 323, leaves us with an average course size of 24, well above the average, 15, and the maximum, 21, reported for the Faculty at large.

In accordance with Tableau, the study credits passed (total and per student that has registered as "active"), the numbers have been as listed in Table 5.

Table 5: passed study credits (total and per student) between 2016 and 2020 (data source: Tableau)

Bestått studiepoeng

	Termin / Studieprogram					
	VÅR			HØST		
	MASV-SYSDY Masterprogram i Systemdynamikk (Modellbasert samfunnsplanlegging)			MASV-SYSDY Masterprogram i Systemdynamikk (Modellbasert samfunnsplanlegging)		
Årstall	Studiepoeng	Aktive	Bestått studiepoeng per stu..	Studiepoeng	Aktive	Bestått studiepoeng per st..
2016	1 135	44	25,80	785	54	14,54
2017	975	46	21,20	1 100	54	20,37
2018	985	40	24,63	760	43	17,67
2019	943	40	23,56	1 050	52	20,19
2020	1 390	47	29,57	0	61	0,00

The maximum (and norm) should be an average 30 credits produced per students. We have already pointed out that the number of students, registered as "active" is not a reliable number and should, realistically, be less. We have, however seen a significant improvement in credits produced per student in the course of the last year. Specifically, the spring of 2020 stands out as remarkably good. These are credits produced by students who passed the first semester hurdle. Notice that the teaching that semester was, for the first time, entirely internet-based due to COVID-19. This is the kind of development that we have been aiming for by way of the improvements in teaching and targeting excellence in the education, possibly causing unmotivated students to terminate their studies after maximum one semester.

To follow up the recommendations of the white paper "Structure and Cooperation", the System Dynamics program would welcome an extensive collaboration across departments and faculties at the graduate level. At its disposal are three of our courses that do not require any prequalification. Similarly, students enrolled in the System Dynamics master program are free to exchange spring semester courses with courses offered by other departments and faculties.

In order to reduce attrition and improve the overall study experiences, two main initiatives have been relevant in the recent past:

Re-design of the second study year

Up until 2017, the study program foresaw a 60 ECTS training component and a 60 ECTS master thesis. As of 2017, we reduced the master thesis to 30 ECTS and, in compensation, added a third course semester, so that the training component now makes for 90 ECTS. The third semester offers methodological specialization courses: GEO-SD309 (Model Based Interactive Learning Environments), GEO-SD330 (Natural Resources Management) and GEO-SD310 (Writing Course and Project Description). In GEO-SD310, students receive training in the thesis writing process, and they iteratively develop a project proposal for their next semester master thesis.

Two full cohorts have by now completed their master thesis according to the new study program and so far, we are very satisfied with the new program. Master theses are of comparable depth to the 60 ECTS theses but they are methodologically more rigorous thanks to the longer training period and they are better designed and planned as a consequence of GEO-SD310.

Peer mentoring

In 2019, we applied for “utdanningsstrategiske midler“ to support the establishment of a peer mentoring culture among master and PhD students in System Dynamics. The project (MINDS – Mentoring in New Dimensions) was aimed at the master students enrolled in the System Dynamics program at the Department of Geography. The overall goal of the peer mentoring project is to enhance students’ degree persistence and success. For this purpose, it provides opportunities for master students to gain authentic experience in their discipline, develop as young professionals, and strengthen their personal and professional identity development. The experience gained from the first year of the pilot project validates our belief that peer mentoring is a valuable approach to assisting master students in improving their skillset and develop as young professionals, as well as establishing relationships and a culture of support among master students. In 2020, the next cohort of students thus took over and has since coordinated the activities initiated by the pilot project:

- Regular meetings among master students, sometimes including PhD students, including participation at the regular System Dynamics Group research seminars.
- Peer Mentoring sessions among master students, following a process akin to that of working groups common at UiB. In these groups, students are able to strengthen their understanding of the concepts presented in their classes and discuss elements of their work at the time as well as further considerations on the nature & specifics of our method.
- Research Interests Meetings where members of both cohorts and recent graduates of the program share their backgrounds, research interests and competencies to facilitate future collaborations, as well as Model Debugging Sessions where students presented their current projects to receive comments and advice by their peers.
- Targeted meetings with mentors, mostly alumni of the master and PhD program in System Dynamics on their experiences with valorising their System Dynamics education in the job market.

2.3 Assessment of the learning environment

We have several measures in place that support an effective learning environment and that we continuously adapt to new circumstances and needs:

Peer mentoring

See MINDS project described under “Opptakskrav og opptakstall”

Study rooms

For many years, students have had the opportunity to work in two dedicated study rooms on the ground floor of Stein Rokkan hus. Given the increasing number of students who needed a working space for focused work on their master thesis, we added a third study room in UPhil hus. This has turned out to be particularly important in the COVID-stricken year of 2020 where, in the fall semester, second year students were able to gather in small groups in one of the study rooms to jointly participate in online lectures.

The room in UPhil is unfortunately only temporary. This one will desperately have to be replaced to ensure a suitable learning environment for students. The study rooms in Stein Rokkans hus are simply not adequate for the number of students that we now have.

Research seminars where master students are also invited

In late 2018, we started inviting the master students to the bi-weekly research seminars in System Dynamics. The purpose of these seminars is for master students, PhD students and staff to present and discuss their ongoing work and project ideas as well as to learn about new developments in the field of System Dynamics – either in the form of guest presentations or joint reading and discussion of articles. With the master students joining these seminars, we have been able to strengthen the integration of master students into the System Dynamics Group at the University of Bergen.

Serious gaming (beer game, C-Roads, Systems Thinking Playbook)

Throughout the master program, we occasionally organize social events that we combine with playing one of the classic serious games in System Dynamics, such as the Beer Game, the Climate Action (En-ROADS) or World Climate (C-ROADS) Simulation Game, and various games from the Systems Thinking Playbook (for Climate Change). The purpose of such events is twofold: first, they are aimed at building and strengthening the System Dynamics community at the University of Bergen and second, they introduce games that can be used by students to familiarize others (incl. potential clients and employers) with the principles of System Dynamics.

Zoom Office Hours

A COVID-19-induced measure is that of Zoom Office Hours separately for first- and for second-year students. As the 2020 cohort started their studies largely from abroad, we felt that we had to create opportunities for students to virtually bump into faculty outside of lecture hours. We have been meeting once a week with both cohorts since the beginning of the semester. Participation is moderate but the measure seems nevertheless to be appreciated as varying problems, questions and concerns can be raised and addressed in a timely manner. The office hours certainly also help the teaching staff to continuously adjust the all-virtual or blended teaching.

3 REQUIREMENTS FOR THE STUDY PROGRAM IN THE STUDY OVERSIGHT REGULATIONS

3.1 Quality assurance system

3.1.1 Quality assurance

Factors that affect the quality of the program

- Resources – staff: The faculty are international leaders in the field and engaged in the students beyond what is considered average (cf. program sensor reports). However, the high workload of the faculty may not be sustainable (cf. section 4.1) and there is a risk of faculty shortage in the near future.
- Resources – external lecturers: The program draws on and is embedded in a global network of researchers and research institutions (cf. section 4.5). Some of our courses are taught by external lecturers who are leaders in their field (e.g. Matteo Pedercini, Vice President and COO of Millennium Institute; William Schoenberg, lead developer at Isee Systems, USA), and we regularly have guest lecturers teaching their specialization (e.g. Yaman Barlas on model validation). A considerable portion of our operational budget is invested in external and guest lecturers.
- Resources – teaching assistants: The other considerable item in our operational budget are the teaching assistants who closely tutor and mentor master students through the different courses. They reinforce the content taught in lectures, complement it with exercises and assignments, and offer personalized modeling support during project work. A cross-cutting theme through course evaluations is the important role that teaching assistants play in achieving course objectives.
- Students /background: Students are enthusiastic and from different countries as well as disciplines. In addition to acquiring the knowledge, competencies and skills for which the master program is designed, students also gain important intercultural and personal skills, simply from studying and working together with peers from very different social and cultural backgrounds.
- Students /peer mentoring: The peer mentoring program described in section 2.1 has contributed substantially to overall study experience.
- The courses are carefully designed with well described objectives and learning outcomes (cf. program sensor reports and section 3.5).
- The program offers many research opportunities (cf. section 3.9) and possibilities for internships (cf. section 3.7.1).
- The master program in System Dynamics is a unique program with international reputation. We encourage our students to be active and present at the annual International Conference of the System Dynamics Society and/or to volunteer for the System Dynamics Society. This not only provides students with networking and feedback opportunities but also demonstrates to them the central role that our master program plays for the field of System Dynamics at large.

- The masters program has been evaluated in the following ways;
    - Annual/biannual program sensor assessments and reports (cf. appendix 5.4);
    - Annual EU-assessments associated with the EMSD program (of which semester 1 and 4 of the local program is a part) for the period 2009 - 2018, including accreditation report in 2009, re-accreditation report in 2014, and final report in 2018;
    - Course evaluations by students (cf. appendix 5.3);
    - Self-evaluation by faculty members (cf. appendix 5.2);
    - Self-assessment to the UiB rector, 2019 (cf. appendix 5.6);
    - Self-assessment to the Faculty of Social Sciences, 2019 (cf. appendix 5.6).

Measures that have been taken as a consequence of the evaluations

- Shift from two to three semesters worth of course work, cf. section 2.1. With the shift to three semesters worth of course work, three additional courses were designed: *GEO-SD 310* (Writing Course and Project Description), where students receive training in the thesis writing process and where they develop a project proposal for their master thesis. *GEO-SD 309* (Model Based Interactive Learning Environments), where students learn about theory, models, methods and techniques for the design, construction and testing of simulation based interactive learning environments portraying complex, dynamic systems. *GEO-SD 325* (Client Based Modeling Project), where students gain practical experience in modeling with and for a real client and thus not only have to focus on the technical aspects of modeling but also on ways of engaging with and successfully delivering for clients. Among the clients we have worked with so far are the Norwegian Refugee Council in Geneva, WWF, UNEP and Climate Interactive.
- System Dynamics education benefits from the use of interactive learning environments (ILEs). Not only does the masters program in System Dynamics make extensive use of such ILEs, it also offers a course in the design and development of such ILEs. The implication is that we teach students in the target group of our ILEs to contribute to the development and testing of such learning environments. This contributes significantly to the relevance, quality, and validity of the learning environments developed in and deployed throughout the program.
- Continued improvements of distance learning courses: To increase the number of online courses and their quality, we obtained an Erasmus+ project to develop 9 new distance learning courses with a focus on System Dynamics applied to sustainability transformation, cf. section 2.1. As preparation, we have developed templates for distance learning courses and for interactive learning environments (ILEs). We have worked with iseeSystems such that their simulation software Stella now passes the accessibility requirements of FutureLearn, the distance learning course provider that the University of Bergen partners with.
- We have also experimented with the flipped classroom model by using distance learning course material for homework and spending classroom sessions with quizzes, discussions, and debriefings. Our experience is that the flipped classroom forces students to think and to express ideas with own words. The hybrid method with distance learning courses seems to be most beneficial for the weaker students.
- Recruitment of domestic students: The recruitment of domestic students has, for years, been hampered by faculty regulations. The common academic pathway for students has been to proceed into masters programs in disciplines included in their undergraduate programs. A cross-disciplinary program, such as the one of System Dynamics, has never been offered in the form of

a bachelors education. In fact, students have been predominantly encouraged to remain true to their undergraduate discipline when aiming for a graduate education. As a consequence, the recruitment of domestic students has been limited. There are currently a number of developments that may remove this barrier against entry: Recognizing the need for transdisciplinary approaches to the challenges faced by our society, the University of Bergen, followed up by the Faculty of Social Sciences, is taking steps to encourage interdisciplinary research and studies both within the faculty and across faculty boundaries. The Global Studies initiative and the cross-facultary PhD stipends exemplify. The new focus will allow for students in other disciplines to be exposed to courses in System Dynamics and may contribute to the recruitment of domestic students into a masters- and PhD program in this field. As pointed out above, the System Dynamics master program is demanding for many students. Therefore, it is important for the quality of the master program that students can prepare by taking introductory courses in System Dynamics at the bachelor level.

3.1.2 Student involvement

- The System Dynamics master program has only recently received its own Program Board. One first-year as well as one second-year student are members of that board and thus directly involved in the further development of the program.
- When we established the Program Board, we decided that all courses would be evaluated each time they are being taught. This allows for quicker feedback from students and more timely refinement and adjustment of courses. For MOOC-based courses, feedback and suggestions for the further development of the courses are directly transferred to the course in Canvas for the subsequent year.
- In GEO-SD325 (client-based modeling project), students can influence some of the teaching activities and content pertaining to the specific client and on a more general needs basis.
- Through the peer mentoring project, the concepts and techniques that students struggle with most are identified and fed into the revision of the corresponding courses next time around.

3.2 Associated regulations

Not applicable.

3.3 Study plan

Content, structure and progression of the master program

The latest version of the course and program descriptions are listed in the appendix. These appendices show the content of the study program. Here, we summarize the structure and progression (Table 6) as well as opportunities for student exchange. Three of our courses do not require any prequalification and are therefore open to students enrolled in other master programs. Similarly, students enrolled in the System Dynamics master program can exchange spring semester (second semester) courses with courses offered by other departments and faculties if they are relevant for their master theses and approved by the department.

Table 6 Structure and progression of the master program in System Dynamics

Semester	Semester focus	Course code	Course name	ECST	Teaching method	Assessment
1*	Methodology – building blocks Individual work	SD302	Fundamentals of Dynamic Social Systems	10	Distance learning course / flipped classroom: Lectures, discussions and assignments	Take home exam (Corona) otherwise online proctored exam
		SD303	Model Based Analysis and Policy Design	10	Lectures, case studies, ILEs, discussions and projects	Take home exam
		SD304	System Dynamics Modeling Process	10	Lectures, computer labs, and major modeling project	Assessment of course project incl. oral presentation
2**	Applications Group work	SD308	Policy Design and Implementation	10	Distance learning course: lectures, assignments	Assessment of modeling project that consists of a simulation model, a report and a video-recorded oral presentation
		SD321	Model Based Socioeconomic Planning	10	Lectures, seminars and computer labs	Assessment of course project
		SD325	Client-Based Modeling	10	Lectures, Seminars, computer labs	Assessment of course project incl. oral presentation
3	Methodology – specialization and dissemination Group and individual work	SD309	Model Based Interactive Learning Environments	10	Lectures and workshops	Assessment of course project incl. oral presentation
		SD310	Writing Course and Project Description	10	Lectures, seminars, and assignments	Assessment of thesis proposal incl. oral presentation
		SD330	Natural Resource Management	10	Distance learning course : Online task, videos, animation, interactive learning environments	Online exam
4	Master thesis Individual work	SD351	Master Thesis	30	Master thesis	Assessment of master thesis incl. oral presentation

* non-master program courses in the first semester

- GEO-SD322 to comply with our obligations in the SIU/DIKU Ukraine exchange program.
- GEO-SD323 to comply with our obligations in the SIU/DIKU North Dakota exchange program.

** The following courses may substitute for a second semester course, with permission of the Department:

- GEO-SD322 Special Topics in System Dynamics, Policy (10 ECTS)
- GEO-SD323 Special Topics in System Dynamics, Applications (10 ECTS)
- GEO-SD324 Special Topics in System Dynamics, Methodology (10 ECTS)

We collaborate with a number of partners who contribute to strengthening teaching (external lecturers). In this way, the teaching becomes relevant and inspiring. Furthermore, these partners bring

guest students with domain competence to Bergen for specialization. The interaction between regular students and guest students creates a mutual enrichment of the environment:

- In 2003, the System Dynamics Group entered into a collaboration agreement on research and education with the Millennium Institute (MI) (NGO), Washington D.C. (https://www.millennium-institute.org). MI conducts model-based analyses with a view to Sustainable Development Goals for a large number of national authorities worldwide. In the course GEO-SD321, Model-based socio-economic planning, the Vice President and COO, Dr. Matteo Pedercini (educated at the System Dynamics Group), gives a four-week intensive introduction to the use of the iSDG model, - the framework model used as a starting point for MI's global work. In this connection, MI brings up to 15 guest students from various national authorities to the course for specialization here in Bergen.
- isee Systems, USA (https://www.iseesystems.com) has implemented the System Dynamics Group's principles for developing and using web-based Interactive Learning Environments (ILEs) in the Stella Architect software. This allows us to realize a seamless work process from modeling, simulation and analysis to web-based communication in the form of ILEs. It is this technology that we now use both in classrooms, in problem solving (case studies) and in distance learning courses that we offer at UiB as well as online. Isee Systems' software developer in this field, William Schoenberg (educated at the System Dynamics Group), offers every year a 3-week intensive introduction to the development of interactive learning environments as part of the course GEO-SD309, Model-based Interactive Learning Environments. This is followed up with project assignments that the students present at the end of the semester, often in the form of single- or multi-user games and often of such great pedagogical value that they are incorporated into our teaching. We invite collaborating organizations to present ideas for ILEs that the students can develop for them.

SIU / DIKU has, for a number of years, financed an extensive exchange of master´s and PhD students as well as faculty with the NaUKMA and the National University of Lviv in Ukraine as well as the University of North Dakota (UND), USA:

- Since 2012 and through several projects funded by SIU / DIKU, the System Dynamics Group, has developed a close collaboration with the National University of Kyiv-Mohyla Academy (NaUKMA) and Ivan Franko University of Lviv in Ukraine. The collaboration is centered around model-based teaching in economics and has attracted over 100 exchange students to our fall courses so far.
- As part of a DIKU-funded collaboration with the University of North Dakota (UND), UiB entered into an agreement with UND in 2013. UiB exchanges students with UND with the main emphasis on the use of modeling and simulation in public health.

Opportunities for student exchange

During the evaluation period, we had 2 students traveling abroad (The Netherlands; Portugal). During the EU-funded EMSD program we did send all of EMSD students to Portugal or Italy. After the second period with funding ended (2018), not many students have traveled abroad, one in 2017 and one in 2018. Instead, as documented above (e.g. section 2.1), many students have arrived Bergen for an exchange semester, most notably in the fall semester of the first study year. These students constitute an addition to our full-time master students.

3.4 Level of learning outcomes

3.4.1 National qualifications framework

So far, we have been using the Dublin descriptors because this was the requirement for the courses in the Erasmus Mundus program. We are aware that we do not fully comply anymore with the NRK guidelines. In the near future, we will therefore update the description of learning objectives so that they are in line with the NKR guidelines.

3.4.2 Name

Not applicable.

3.5 Learning outcomes and infrastructure

3.5.1 Content and structure

Table 7 is a map of the study program that shows how the individual courses and their progression over the semesters, contribute to reaching the overarching learning objectives of the master program in System Dynamics.

Drawing this map helped us identify some minor mismatches between course descriptions and overall learning objectives. For example, we realized that the learning objective “The candidate knows at least one System Dynamics software package and is aware of others” has not been updated to cater for a major transition some years ago where all courses are now very consciously taught using the Stella Architect software. This software provides a seamless transition between modeling, simulation, parameter estimation, model analysis, optimization and the development and testing of interactive learning environments. In short, - in as a tool that covers the needs of a professional system dynamicist. In part, the development of this software has been based on research conducted as part of the masters and PhD program in System Dynamics. In order to boost their awareness re. the magnitude and variety of methods, techniques and tools available to their profession, students in the program are exposed to additional software packages and are made aware of their applicability across a variety of domains.

The master program is based on a spiral learning approach, where the core methodological content taught in the first semester is repeatedly reinforced in successive semesters and in varying contexts: application (second semester), methods (third semester) and dissemination (third and fourth semester). This repetition moves upward along a spiral as more advanced concepts build upon basic ones, also within the first semester.

While the first semester focuses on individual work and learning, interpersonal skills and collaborative learning become more important as of the second semester, where all courses are based on group work. In the third semester, different forms of dissemination are presented, ranging from a course on the design of model based interactive learning environments to a distance learning course that demonstrates internet-based learning.

Table 7: Study program map

I: introduces *S: strengthens* *M: masters*	**1. semester**			**2. semester**			**3. semester**			**4. semester**
	302	**303**	**304**	**308**	**321**	**325**	**309**	**330**	**310**	**351**
Knowledge – The candidate …										
… knows inherent challenges in understanding the dynamics of social systems	I	I	I	S	S	S	M	M		M
… knows the System Dynamics paradigm and alternative methods of analysis	I	I	I	S	S	S	M	M		M
… knows System Dynamics applications to problems in public and private sectors	I	I	I	S	S	S	M	M		
… knows how system structure can be portrayed in terms of stocks, flows, and feedback	I	S	M							
… knows behaviors that arise from fundamental structures of dynamic systems	I	S	S	M	M	M				
… knows at least one System Dynamics software package and is aware of others	I	S	S	M	M	M				
Skills – The candidate …										
… is able to define problems, observe client perspectives, and assess importance	I	I	I	S	S	S	S	S		M
… is able to build on theory to formulate hypotheses about problem causes	I	I	I	S	S	S	S	S		M
… is able to build on and transfer knowledge from related cases	I	S	S	M	M	M				
… is able to analyze hypotheses in terms of realism and ability to explain problems	I	I	I	S	S	S	S	S		M
… is able to explain behavior, detect weaknesses, and reformulate hypotheses	I	I	I	S	S	S	S	S		M
… is able to evaluate the usefulness of hypotheses as theories/models for policy analysis	I	I	I	S	S	S	S	S		M
… is able to identify new policies and to test these by way of simulation	I	I	I	S	S	S	S	S		M
… is able to communicate with clients to overcome hinders for implementation	I	I	I	S	S	M	M			M
… is able to report to an academic audience showing equations, diagrams, and graphs	I	I	I	S	S	S	S	S	M	M
… is able to contribute to the literature and to theory building	I	I	I	S	S	S	S	S	M	M
Competence – the candidate …										
… can engage in discussion with class mates, with colleagues, and with the general public	I	I	I	S	S	S	M	M	M	M
… can write and speak effectively	I	I	I	S	S	S	S	S	M	M
… can take ethical considerations into account when conducting research and interacting with clients, stakeholders, and colleagues	I	I	I	S	S	S	S	S	M	M
… can seek the roots of problems and avoid overconfidence in quick fixes	I	I	I	S	S	S	S	S	M	M
… can quickly transfer knowledge from basic models to a multitude of problem areas	I	S	S	M	M	M	M	M		M

3.5.2 Infrastructure

The master program has overall good access to necessary and suitable infrastructure (with infrastructure being understood in a very broad sense, including premises, equipment, library services, administrative and technical services, adequate and suitable ICT resources, web support, learning platform). Study rooms are hard to find and the one room in UPhil is unfortunately only temporary. This one will desperately have to be replaced to ensure a suitable learning environment for students. The study rooms in Stein Rokkans hus are simply not adequate for the number of students that we now have.

Our master program is based entirely on the Stella Architect software. We have good relations with the software provider in general and to the developers specifically. In the future, it will be desirable to negotiate a better deal when it comes to continuation of the software subscription for recent graduates to give them a flying start. Currently, they are downgraded to Stella Professional upon completion of their studies.

3.6 Teaching and assessment methods

To address the topics of teaching and assessment methods and how they contribute to the students achievements of the overall learning objectives, we need to refer to several elements discussed earlier in this report:

- For the teaching and assessment forms of the individual courses, cf. Table 6.
- Progression through the individual courses towards the overall learning objectives of the master program follows a spiral learning approach, cf. section 3.5.1.
- The study program map lists how the individual courses contribute towards achieving the overall learning objectives of the master program.

Based on all of these considerations and supported by the course as well as program evaluations discussed in section 3.1.1, we conclude that our students achieve the overall learning objectives of the master program in System Dynamics.

Changes in the teaching and assessment methods:

- As of the fall 2020 semester, written exams have been replaced by take home exams. In addition, we have thoroughly reviewed the entire study plan and made changes in teaching as well as assessment methods.
- We constantly fine-tune the teaching method and content and adjust the mix of teaching styles (asynchronous distance learning courses vs. on-campus, synchronous teaching).
- For student involvement in the fine tuning and further development of teaching and assessment methods, cf. section 3.1.2.

3.7 Academic content

3.7.1 Academically updated study program

We frequently update our teaching content so as to remain relevant relative to the developments of the field of System Dynamics, - as well as developments in important application domains.

- We are spearheading some of the methodology development ourselves within the field of System Dynamics, e.g. in the domains of interactive learning environments, online teaching, model analysis and participatory modeling. These developments are directly integrated into our teaching (e.g. group model building workshops in person and online as part of course work; model analysis methods) – or arise at least partly from our teaching (e.g. MOOCs).
- We are constantly aware of the need to reorientate the application of our method to fields that are essential with respect to society at large and UiBs Priority Areas in specific. While students remain free to work on their application area of choice, we have streamlined especially the application courses in the second semester courses towards the three Priority Areas, with a focus on sustainable development and resilience. In these courses, we practice a comprehensive, cross-disciplinary approach and thus illustrate how System Dynamics can contribute in a comprehensive and systemic way to problem analysis and solving.
- We seek collaborations with private and public sector entities to facilitate internships and project work for our students (in the recent past, e.g. copernicos groep, Cap Gemini, System Dynamics Society, Millennium Institute, Bergen Kommune, Startup Lab). This has a double benefit: On the one hand, these internships and projects provide students with important work experience. On the other hand, we keep up to date with developments in working life and society.
- In GEO-SD325, we work with new clients every year. They bring their specific challenges to the course, which has similar benefits than those described for internships and project work.

3.7.2 Relevance

System Dynamics is, by nature, aimed at the identification and solution of complex, dynamic problems that exist in reality. As such the theory, methods, techniques and tools applied are tailored to strategy developers, policy designers and decision makers challenged by real life complexities that unfold over significant periods of time: The reality and significance of

- time-consuming processes that separate cause from effect in time as well as space;
- feedback processes that call for circular reasoning;
- non-linearities that cause synergy and call for coordination;
- stochasticity and uncertainty that call for caution,

are all being recognized and effectively addressed. The relevance of the program to working life is illustrated by the fact that the EU recognized the European Masters Program in System Dynamics (EMSD) of which the System Dynamics program in Bergen is a cornerstone, as an Erasmus Mundus program for 9 years. This is a program that predominantly hosts educations of significant professional relevance. As required by the EU, a tracer study of the students in that program demonstrated that 51% of the students were hired permanently within 1 month of the completion of their education (long before they had received their diplomas). 82% of the EMSD students reported that they applied their System Dynamics on a daily basis in their profession. 40% pursued an academic career, while as 25% went into management consulting, 13% to IT, 10% to the public sector and NGO and the remaining to miscellaneous services in the private sector. Due to privacy concerns, a similar

tracer study has not been conducted on non-EMSD students, but there is no reason to believe that there is a significant discrepancy between the two groups of students. Appendix 5.6, the 2019 report to the Dean of the Faculty of Social Sciences and the Rector of the University of Bergen, also contains a table with results from a tracer on PhD graduates in System Dynamics. That table also demonstrates excellent career opportunities of graduates.

Relevance for working life; students' career opportunities

The master program in System Dynamics is a demanding interdisciplinary program that produces people with systems thinking skills that are much in demand in industry as well as in governments. There is increasing understanding for a need for an integrated perspective for addressing societal problems. System Dynamics is well suited to take on this challenge.

According to the Rector of the University of Bergen, Dag Rune Olsen (our translation): "Traditionally, academia's approach to problems is largely disciplinary. Within disciplines, we try, through well tested reductionism, to delineate, simplify, and reduce the problem to something that existing scientific methods can handle… .Systems theory and systems analysis is a methodological approach well adapted to complex problems and gives a holistic understanding where reductionism leads to tunnel vision."

For more details about the relevance of the master program in System Dynamics for working life and students' career opportunities, we refer to the following letters (cf. appendix 5.5):

- Dr. Hans Herren
- Dr. Jack Homer
- Dr. Matteo Pedercini
- Dr. Andrea Bassi
- Professor Bent Erik Bakken
- Professor Michael Radzicki
- Professor John Sterman
- Professor John Morecroft
- And the following statement from Kim Warren:

  It is a pleasure to endorse the Master program in System Dynamics at the University of Bergen. I have been involved with its faculty and students for many years and have always admired the high standard of those students, the strength of its pedagogical foundations and the relevance of the program's content to the real world. The large and diverse list of reports and papers from students and their supervisors over a long time show a strong commitment to solving real-world challenges. It has also been my pleasure to work with students of the program during some of their field-work assignments, and both I and their clients have been impressed with their intellect and the practicality of their work.

  Kim Warren: linkedin.com/in/kimwarren/

Discussions with current students and recent graduates revealed that one important factor that contributes to employability and career opportunities lies in the soft skills that students acquire throughout the master program. Soft skills, in this context, refer to a variety of things:

- Intercultural skills acquired from working as well as learning with fellow students from largely varying cultural and geographical backgrounds. The understanding and perspectives gained

from this intercultural mix of students is a big selling point of the master program in System Dynamics that is not immediately visible from the outside.

- Another important soft skill is the fact that students not only become modelers but systems thinkers. Going through the program is an aha-experience because it provides a new way of thinking. On the basis of simple principles, graduates can map complex contexts and understand what factors are important. Not least this is important in presentations, also in jobs that do not involve System Dynamics modeling on a day-to-day basis.
- Entrepreneurial spirit: As there is not one clear job market for system dynamicists, it becomes important already during the study program for students to make themselves visible in the form of projects and collaborations that they acquire. Students rise to this challenge and self-organize. They bring System Dynamics to their student job employers, participate in hackathons and challenges (the most recent being the Bergen 2030 challenge, https://www.20tretti.no/).

Relevance for further studies

An unusually large share of the master students that graduate from the System Dynamics program continue as PhD students, both in Norway and abroad. It is our understanding that they are inspired by their experience with the problem oriented scientific method that they learn and practice in the master program.

For more details about the relevance of the master program in System Dynamics for further studies, we refer to the following letters (cf. appendix 5.5):

- Professor John Sterman, in his letter dating back to 2015.
- Dr. Matteo Pedercini
- Dr. Andrea Bassi
- Professor Michael Radzicki

Relevance for further studies as expressed by graduates of the Master in System Dynamics:

The deep understanding of the methodology of System Dynamics as well as of the breadth of applications of the method that is communicated and practiced throughout the course of the master's program allow for diverse opportunities for further studies. Graduates of the program are qualified to apply for and receive offers for PhD programs in numerous disciplines (e.g. Sustainability, Public Health, Human Behaviour), effectively engage in collaboration with researchers in broader fields dominating contemporary scientific discourse (e.g. Computational Social Science, Complexity Science, Data Science), and contribute significantly to the effort of Science Communication (SciCom). Moreover, the strong methodological foundations as well as overall strength of the System Dynamics methodology allow graduates to secure positions beyond those directly calling for the specific method, disseminating and opening new paths for the System Dynamics methodology.

One final point that we would like to mention with respect to relevance for further studies are the publication activities of our master students during and immediately after their studies. Here is an incomplete list of publications (journal and conference) produced by master students during the evaluation period:

- Spicer, J. (2015). Representation and dynamic implications of mental models of food systems. A case study of dynamic decision making of small-scale farmers in Zambia. Paper presented at the 33rd International Conference of the System Dynamics Society, Cambridge, MA.

- Khan, A.; Kopainsky, B.; Lee, C.; Farha Alias, E.; Avila, L.(2018). Best Publishing Practices for Non-System Dynamics Journals: Questionnaire Design. Paper presented at the 36th International Conference of the System Dynamics Society, Reykjavik, Iceland.
- Gusheva, E. (2020). Beyond the tragedy of open access: an exploratory model of governance rules for the commons. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual. (Best Poster Award Winner)
- Gkini, C.; Shresta, A.; Kopainsky, B. (2020). Empowering Communities: Power devolution in Community-Based Natural Resources Management. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual.
- Xiang, Min. (2020). 304 Design Company Case Analysis. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual.
- Xiang, Min with Kave Jangi and David Wheat. (2020). System Dynamics Applied on Marketing to Push Nokia Back to the Best-Selling Mobile Phone Brand in 2030. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual.
- Niño Giraldo, Nathalia (2020). Sustainability of Pance River as a Water Resource. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual.
- Cole, Nathan Waldner with Richard Ruston (2020). Shining a Light on Norwegian Opioid Overdoses. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual.
- Ruston, Richard (2020). Volunteer Technicians at Den Akedemiske Kvartertet. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual.
- Noyes, Will (2020). Development of the United States Senior Housing Industry. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual.
- Batinge, Benjamin (2020). Modelling gendered innovation for the security of energy services in poor urban environments. Paper presented at the 38th International Conference of the System Dynamics Society, Virtual.
- Batinge, Benjamin with Josephine Musango, Alan Brent and Cherie Forbes (2019). Roadmap for universal electricity access and renewable energy targets in Ghana. Paper presented at the 37th International Conference of the System Dynamics Society, Albuquerque, NM.
- Duminy, Lize with Josephine Musango, Benjamin Batinge, Ian Taverner, Martin Viljoen, and Suzanne Smit (2018). From model results to implementation in practice: the case of Mohair Value Chain Sustainability Project. Paper presented at the 36th International Conference of the System Dynamics Society, Reykjavík, Iceland.
- Batinge, Benjamin with Josephine Musango and Alan Brent (2017). Boosting electricity access in Africa with private sector financing. Paper presented at the 35th International Conference of the System Dynamics Society, Cambridge, MA.
- Batinge, Benjamin (2015). The Effect of Information Design and Presentation on Decision-Making Strategies and Performance in a Dynamic Environment. Paper presented at the 33rd International Conference of the System Dynamics Society, Cambridge, MA.
- El Hachem, Wissam with Pietro De Giovanni (2018). Transition to Alternative Fuel Vehicles: A Distributive Justice Perspective. Paper presented at the 36th International Conference of the System Dynamics Society, Reykjavík, Iceland.
- Hafner, Sarah with Tomas Hubik, Joona Tuovinen, Hector Menendez and Thomas Horschig (2017). We Like Each Other – Is this the Systemic Solution for the Survival of Peer Mentoring Groups. Paper presented at the 35th International Conference of the System Dynamics Society, Cambridge, MA.
- Wilson, Benedicte (2017). The dynamics of female labour force participation: how family policy influences womens work behaviour. Paper presented at the 35th International Conference of the System Dynamics Society, Cambridge, MA. (Best Poster Award Winner)

- Katz, Stefan with Stefan Groesser (2018). Building confidence in Simulation Models using automated analyses. Paper presented at the 36th International Conference of the System Dynamics Society, Reykjavík, Iceland.
- Katz, Stefan with Stefan Groesser (2015). Dynamic Balanced Scorecard: Taking stock and looking ahead. Paper presented at the 33rd International Conference of the System Dynamics Society, Cambridge, MA.

How the relevance for working life and further studies is communicated to the students

Here, we refer back to section 3.7.1 and forward to section 4.5.

In terms of further development of the master program, discussions with current students and recent graduates revealed that they would appreciate a clearer overview of the opportunities available after graduation and of the different pathways. We are in the process of integrating this valuable suggestion into the re-design of our website, into the recruitment process for new students and into the ongoing teaching and interaction with students.

Schemes for interaction with working and social life

Here, we refer back to section 3.7.1.

3.7.3 For master programs

The profile of the master program has already been documented extensively in sections 3.3 and 3.5. Regarding academic breadth, we highlight that the study program covers methodological aspects of the System Dynamics approach in depth as well as a variety of application areas (most notably, through the second semester courses) and dissemination formats (distance learning courses and ILEs). Our students enter the master program with diverse academic backgrounds. There is thus great academic breadth in the types of issues that are addressed in the course of the master program, most notably in the master theses, where students can self-select their topics.

3.8 Scope of work

As all courses in the program are taught sequentially so that there is no competition in work-demand between courses. Each teaching semester consists of 3*10 ECTS and the fourth semester is dedicated to a 30 ECTS master thesis.

Especially during the first year, the work load is certainly closer to 1800 hours than to 1500 hours. The System Dynamics master program is an ambitious program that requires students to work very hard. The program sensor report repeatedly documents that second-year students usually are of the opinion that the hard work during the first year, especially during the first semester, is necessary to acquire the knowledge, skills and competencies that are crucial in applying System Dynamics to real world problems in their master theses. While it is difficult to considerably lessen the workload in the first semester, we are constantly working on improving the support that we provide students with in terms of tackling the challenges of learning a new methodology.

3.9 Links to research

Section 4.5 gives a comprehensive overview of the ongoing research projects at the System Dynamics Group. In the last row, it also summarizes how students are involved in these projects or how these projects are connected to teaching.

In addition to these connections to research, we would also like to refer to other activities previously mentioned:

- The bi-weekly research seminars in System Dynamics, cf. section 2.3, page 13.
- Participation in the International System Dynamics Conferences, through poster and paper presentations, cf. section 3.1.1.
- Peer mentoring project and joint activities with PhD students, cf. 2.1.

3.10 Internationalization

The System Dynamics Group is the most prominent center for System Dynamics education and research in Europe and, arguably, on a world basis. Historically (since 1995), 4 of its 6 professors have been foreigners, - and no less than 98% of our students likewise.

The System Dynamics Group participates over and beyond its capacity in a significant number of international research projects, cf. section 4.5.

In terms of education, both the university and the Faculty of Social Sciences emphasize the need for English as a language of instruction, for a significant inflow of foreign students, and for a corresponding exchange of native students with partner HEIs. The System Dynamics program was originally established as an international program serving merely foreign students. The language of instruction has always been English, and the program was only opened to Norwegians as late as in 2000. Of the well over 300 graduates, nearly all have been foreigners. Consequently, the program has contributed significantly to the recruitment of foreign UiB students targeting the Faculty of Social Sciences, and it will continue to do so.

The most significant effort in terms of student exchange was the European Master´s in System Dynamics (EMSD). For 9 years this education was funded by the EU and recognized as an Erasmus Mundus program. It allowed students to study in Norway, Portugal or Italy and the Netherlands. As a successor of the Erasmus Mundus program, we are currently finalizing a memorandum of agreement with the same universities to ensure future student exchange and, as coordinator, the University of Bergen has been charged by its partner institutions to apply for an Erasmus Mundus status based on a re-structured version of the EMSD program that benefits from our advances in the ERASMUS+ project currently underway (see below).

The Erasmus+ program “Systems analysis MOOCs for sustainability transformation” with its consortium of six partners will additionally facilitate student exchange in a significant way.[2]

[2] The Erasmus+ project “Systems analysis MOOCs for sustainability transformation” will develop 9 distance learning courses that together will form the core of a web-based education at master and bachelor level in System Dynamics for sustainability transformation. The partners behind this initiative are the consortium of universities offering the EMSD program as well as the Università della Svizzera Italiana and Riga Technical University.

An overview of student exchanges in the past was provided earlier in section 3.3.

The NGO Millennium Institute, a close partner of the GSD, has annually, for the last 12 years, recruited public governmental officials to our GEO-SD 321 course in Model-based Development Planning. They originate from nations in the developing world, predominantly Africa, and are trained to apply the System Dynamics model "iSDG" to support comprehensive development planning with a focus on SDGs. Since the 1990´ies, the Millennium Institute has been undertaking well over 50 model-based national development projects based on the System Dynamics method and was, in 2017, awarded the Applications Award by the System Dynamics Society.

The University of Bergen is currently working towards an agreement with the Université, Paris 1, Panthéon-Sorbonne, that is aimed at a joint / double masters degree in data management associated with complex, dynamic systems. In collaboration with the System Dynamics Group, the program will offer a significant component of System Dynamics and will be financed by a consortium of French industrial corporations that offers secondments for students in the program.

In conclusion, the System Dynamics Group is an internationally oriented academic entity with an agenda to serve the wider community of researchers and practitioners worldwide with the knowledge and skills to professionally conduct research, offer education, and exercise management, in complex, dynamic domains and to undertake model-based knowledge dissemination to a wide variety of audiences worldwide.

3.11 Practice

Not applicable.

4 REQUIREMENTS FOR THE ACADEMIC ENVIRONMENT IN THE STUDY OVERSIGHT REGULATIONS

4.1 Size of the academic environment

The System Dynamics program has been offered by the University of Bergen since 1995 and, since 2000, with notable exceptions, by 3 full-time associate and full-time professors. The reputation of the program and the associated EMSD program has caused the number students to grow significantly. And so has the production of credits and candidates along with the productivity of the faculty members offering the program. In 2019, we were at a point when the Faculty Board recognized the need for making sure that the System Dynamics Group would remain at no less than 3 persons. Albeit too few to satisfy the growing demand for such an education, we are currently at a point where we can develop a strategy on how to proceed so as to calibrate our production to the resources allocated with a clear focus on quality in education and development of an innovative pedagogy based on advanced software technology and electronic presence.

To address the question as to whether the resources allocated to the masters program in System Dynamics is in proportion to the production accomplished, we paraphrase the 2019 report to the UiB rector and the Faculty of Social Sciences.

The System Dynamics Group encompasses 3 professors, two of whom will retire in 2022. Table 8 indicates the productivity (and thus the work pressure) of the System Dynamics Group (GSD), in terms of student-years produced per academic staff member, relative to the Social Science Faculty (SV-fak) at large. The numbers are based on the long term (3-year average) production of student-years (2015 – 17), employed by the Faculty in its allocation of positions in 2018, and the short-term production of student-years (2017) employed by the Faculty in its allocation of the annual budget in 2018.

Table 8: The productivity of the System Dynamics Group.

Long term production of student-years per employee (faculty member) (3-year average)			
Program	**GSD**	**SV-fak**	**Relative productivity SDG / SV-fak**
Master	31	17.79	**1.78**
Short term production of student-years per employee (faculty member)			
Program	**GSD**	**SV-fak**	**Relative productivity SDG / SV-fak**
Master	34.5	18.4	**1.88**
Budget 2019 per employee (faculty member); - a reflection of productivity			

Year	GSD	SV-fak	Relative productivity SDG / SV-fak
2019	370 000 NOK	160 000 NOK	**2.26**

The red numbers in the column left demonstrate that the System Dynamics Group is under-staffed relative to the Faculty at large, in an amount estimated to correspond to 1.3 positions. Due to the mechanisms governing the allocation of positions at the Faculty of Social Sciences, no such allocation may be expected to take place. An assessment of the strategic significance of the System Dynamics Group has, nevertheless, led the faculty board to the conclusion that the two faculty members retiring in 2022 will be replaced and that the replacement process will start no later than 2021.

The academic staff has been very stable over the years. Two of the staff members were appointed by the University of Bergen in 1984 and 2000, respectively. Three years ago, a third staff member retired after 10 years of service and was immediately replaced by a senior researcher who had served the System Dynamics Group for a corresponding period of time and who was, shortly thereafter, granted a promotion to full professor. All three professors currently serving, have also served as presidents of the System Dynamics Society, the international organization of system dynamicists. Both employees and students have been awarded honors by that society for their work in the field and the academic staff has a publication list that reflects to the world-wide recognition of the program under re-accreditation.

As documented above, the System Dynamics program is an international program based on outreach and collaboration with a wide variety of institutions abroad. So is the research portfolio documented above.

The System Dynamics program is research-based and has been designed over the years, tailored to the research interests of the academic staff. This is done to make sure the program is covered by the academic staff in terms of competence and skills and so that it brings out the enthusiasm and dedication to the field, required to ensure that a world class education is being offered.

4.2 The academic environment's educational competence

The pedagogy of System Dynamics requires specific skills in the field itself. The essence of that pedagogy is to effectively communicate the relationship that exists over time between structure and dynamics of complex dynamic systems. The pedagogy is, moreover, anchored in educational theories, techniques and tools (software) that is being employed in the delivery of the insight gained from our systems studies. Consequently, special skills in Community Based Group Model building and in the development, deployment, and assessment of model based Interactive Learning Environments (i.e. educational technology) is at the heart of the educational skills required to teach in the field.

Pål I. Davidsen is a Professor of Educational Information Science and established the Educational Information Science and Technology Center at the University of Bergen, led by Dr. Michael Spector, professor of philosophy and educational technology. For a number of years, he was also Head of the Educational Information Center at the University of Karlstad. He was co-director of the UROP project lead by Jay W. Forrester at MIT, a project that spear-headed the development of model-based

educational software for American schools. He has been teaching the course in interactive learning environments (ILEs) since around 2000 (together with William Schoenberg since 2018).

Professor Erling Moxnes is a specialist in the development of model-based distance learning courses and on flipped classrooms. Assisted by Steven Alessi, Associate professor of Educational Technology, he developed the first scoring distance learning course offered globally by UiB, a course in Natural Resources Management that has since been offered a component in the standard course portfolio in the masters program in System Dynamics. He is currently the coordinator of an ERASMUS+ project

Professor Birgit Kopainsky has been trained as a Community / Group Model Building expert and has extensive experience in the field from across the world. She has also contributed significantly to the design and assessment a number of model-based Interactive Learning Environments.

Since 1995, the System Dynamics Group has been a world leader in the development, deployment, use, and assessment of model-based interactive learning environments. The group has inspired the development of software for model development, analysis and web-based dissemination of insights into complex, dynamic systems. The course GEO-SD 309 (initially 305) in interactive learning environment development has always been an essential component in the program curriculum. This has opened up for the development of distance learning courses with groundbreaking content. The course GEO-SD 330, Natural Resources Management, has been developed and is now delivered on the basis of such technology and is the first scoring distance learning course offered globally by UiB. Our vision is clearly to remain a leader in digital education, and we are currently developing a number of course components based on the new technology that will be integrated in a program in System Dynamics deployed by way of web.

The competence held by the System Dynamics Group in this field, has inspired our partners both in the EMSD program and beyond to collaborate with us in the development of project proposals addressing the EU and other funding agencies. These proposals range from the Erasmus Mundus proposal in which there is a strong emphasis on the utilization of ILEs in graduate education; the recently funded Erasmus+ project, entirely focusing on MOOC-based distance learning at the undergraduate level; the Marie Curie proposal with a very strong focus on ILE-based knowledge dissemination within the SDG domain; and the Belmont Forum COAST Card project focusing on ILE-based, transformation of polluted bay-areas across USA and East Asia.

The development and application of distance learning course technology is facilitated by our close research collaboration with isee Systems (USA) producing the Stella Architect software. Isee Systems´ developer is a graduate of the master as well as PhD program in System Dynamics. Moreover, Isee Systems´ ILE technology is fully in compliance with Canvas, the outreach technology employed by UiB.

Here is a selection of publications by professors and PhD students in the System Dynamics Group, and many times visiting scholar Professor Stephen Alessi, from in the Education Department at the University of Iowa. The publications demonstrate a great interest in teaching and learning by faculty and students in the group.

Alessi, S. and B. Kopainsky (2015). "System Dynamics and simulation/gaming: Overview." *Simulation & Gaming* **46**(3-4): 223-229.

Alessi, S. M. and S. R. Trollip (2001). *Multimedia for learning: Methods and development*, Allyn & Bacon. **(cited 2675 times)**

Kopainsky B., Alessi S.M. (2015). Effects of structural transparency in System Dynamics simulators on performance and understanding. *Systems* **3**(4): 152-176.

Kopainsky B., Alessi S.M., Pedercini M., Davidsen P.I. (2015). Effect of prior exploration as an instructional strategy for System Dynamics. *Simulation & Gaming* **46**(3-4): 293-321.

Kopainsky B., Pirnay-Dummer P., Alessi S.M. (2012). Automated assessment of learners' understanding in complex dynamic systems. *System Dynamics Review* **28**(2): 131-156.

Kopainsky B., Sawicka A. (2011). Simulator-supported descriptions of complex dynamic problems: Experimental results on task performance and system understanding. *System Dynamics Review* **27**(2): 142-172.

Kopainsky B., Pedercini M., Davidsen P.I., Alessi S.M. (2010). A blend of planning and learning: Simplifying a simulation model of national development. *Simulation & Gaming* **41**(5): 641-662.

Moxnes, E. and A. K. Saysel (2009). "Misperceptions of global climate change: information policies." *Climatic Change* **93**(1-2): 15-37.

Saldarriaga, M., B. Kopainsky and S. M. Alessi (2013). *Knowledge analysis in coupled social--ecological systems*. the31st International Conference of the System Dynamics Society, Cambridge, MA.

Tadesse, A. T. and P. I. Davidsen (2019). "Framework to support personalized learning in complex systems." *Journal of Applied Research in Higher Education*.

Taminiau, E. M. C., L. Kester, G. Corbalan, S. M. Alessi, E. Moxnes, W. H. Gijselaers, . . . J. J. G. V. Merriënboer (2013). "Why advice on task selection may hamper learning in on-demand education." *Computers in Human Behavior* **29**(1): 145-154.

Wheat, I. D., A. Tadesse, M. Li and G. Lewis (2013). *Teaching Policy Design: Using a Case Study of Unintended Consequences When the EU Regulates Hospital Doctors' Hours*. Proceedings of the 31st International Conference of the System Dynamics Society, Cambridge, MA, USA.

4.3 Academic management

Since the beginning of 2020, the master program in System Dynamics has had its own program board. Members of the board are:

- The three professors in System Dynamics
- One first-year and one second-year master student representative
- A PhD student representative
- An external member of the board (prof. Nuno Videira, Universidade Nova de Lisboa, Portugal).

Quality assurance and development are clearly defined, as evidenced, for example, by the decision of the Program Board to evaluate all courses each time they are being taught.

4.4 The academic environment's subject-specific competence

The System Dynamics Group is the most prominent center for System Dynamics education and research in Europe and is considered, in many respects, on par with the corresponding group at MIT. The three faculty members in the System Dynamics Group are leaders of the field of System Dynamics. This is, for example, evidenced by the fact that all of them have served as the president of the international System Dynamics Society, and that two of its employees have received, respectively, the Jay W. Forrester Award and the SDS Distinguished Service Award. A number of students have, over the years, been awarded the Donella Meadows Award for the best student work at the yearly International conference in System Dynamics.

Professor Pål I. Davidsen founded the System Dynamics Group at the University of Bergen. He has pioneered the development of ILEs, has developed a technology for online internet games (the one

that was later implemented in Stella Architect), and has worked on projects with a wide variety of clients, for instance in management education, energy, and health care administration. He is currently involved in one EU Horizon 2020 project, one EEA Norway grant in collaboration with RTU, and an international Belmont Forum project on ocean management. He was the 2003 President of the System Dynamics Society.

Professor Erling Moxnes has a PhD in System Dynamics from Dartmouth College and is an expert in natural resources management and in the dynamics of markets (commodity markets, energy markets, and macroeconomics). He pioneered the use of computerized laboratory experiments in Norway and was the first in Norway to develop and offer a distance learning course in the MOOC tradition. He has received the Jay W. Forrester award for an article in Management Science revealing severe misperceptions and mismanagement of renewable resources in cases where there is no commons problem present. He was the first to propose, analyze, and argue for the establishment of the now 10,000 billion kroner Norwegian Petroleum Fund with the strict rule for use of the fund that was put in place. Beyond standard System Dynamics, he has developed software for advanced optimization under uncertainty and published articles on natural resources decision-making under uncertainty. He was the 2009 President of the System Dynamics Society. He is currently in charge of the Erasmus+ Strategic partnership to develop 9 distance learning courses.

Professor Birgit Kopainsky is an expert in System Dynamics and has worked mainly on strengthening the role that System Dynamics can play in facilitating transformation processes in social-ecological systems such as the transformation towards sustainable and resilient agri-food systems. She is currently involved in two Horizon2020 projects and is a member of the Bærekraftskollegiet at the University of Bergen. She also teaches a course in System Dynamics for agricultural scientists at ETH Zurich. Her research has pushed the frontier in participatory model building several times, e.g. when adjusting the method to settings in rural Africa or when taking the method online during the Covid-19 pandemic. She is the current and first ever female President of the System Dynamics Society.

4.5 International and national collaboration

We have a multitude of ongoing research projects with a variety of national and international partners and from a variety of funding sources (Table 9). We also collaborate with national and international partners in various forms on educational offerings (Table 10).

Table 9: National and international collaborations – research

Project name	Funding source	Main collaboration partners	Student involvement
Co-Create (Confronting obesity: Co-creating policy with youth)	EU Horizon 2020	Folkehelseinstituttet (coordinator)	GEO-SD309
SURE Farm (Towards SUstainable and REsilient EU FARMing systems)	EU Horizon 2020	University of Wageningen (coordinator)	Research assistance
COAST - Coastal Ocean Assessment for Sustainability and Transformation», the University of Maryland	Belmont Forum	University of Maryland (coordinator)	GEO-SD309
Africa's Coexistence Landscapes: Securing their Future for People, Elephants and other Wildlife	DG ENV / DG DEVCO ENRTP-GPGC Strategic Programme	United Nations Environment Programme	GEO-SD325
GreenHeat: Towards collaborative local decarbonization	EEA and Norway Grants (Poland): IdeaLab	Polish Academy of Sciences (co-ordinator)	Research assistance

Project name	Funding source	Main collaboration partners	Student involvement
Model-based analysis and management of restructuring processes in the construction industry	Swiss National Science Foundation	University of Applied Sciences St. Gallen, CH; University of Rapperswil, CH (co-ordinator)	
Reinforcement grant to EU Horizon 2020 project SURE Farm – Towards SUstainable and REsilient EU FARMing systems	NFR	Department of Geography, UiB/NMBU	Master thesis
New Waterways - towards water-sensitive and climate-adapted Nordic cities	NFR Klimaforsk	NIVA (coordinator)	Research assistance
Dyphavsressurser - innovasjon, eksplorasjon, produksjon	Cross-faculty PhD position, priority area “marine research”	Department of Geology, UiB	Master thesis
Models for Innovative Collaboration in sustainable land use issues	Cross-faculty PhD position, priority area “climate and energy transition”	SLATE, UiB	Master thesis
Theory, methods, techniques and tools for modeling, analysis and optimization of complex dynamic systems and for dissemination of system insight	isee Systems, USA	isee Systems, USA	All GEO-SD courses
Designing online interactive learning environments to support learning in and about complex dynamic systems	Quota scheme	isee Systems, USA	Master theses
Malaria, - a model-based analysis of the epidemiological development in Kenya and Ethiopia	UiB, Millennium Institute	Millennium Institute	
Sustainable utilization of land through planning based on a synthesis of System Dynamics and geographical information systems	KnowlEdge srl	KnowlEdge srl	
Conditions for the sustainable commercialization of technologies for carbon capture, storage and exploitation in oil production	University of Palermo, joint PhD program	University of Palermo	
Financial and physical conditions for a sustainable crude oil market	University of Palermo, joint PhD program	University of Palermo	
Conditions for a sustainable system for safeguarding public health in Lombardy (Italy) with a focus on chronic diseases	University of Palermo, joint PhD program	University of Palermo	
Food security in Malaysia	National stipend, Southeast Asian Regional Center for Graduate Study and Research in Agriculture, Universiti Putra Malaysia	Universiti Putra Malaysia	
Analysis of the conditions for private companies' financial sustainability	National stipend (Pakistan)	The Woman University, Multan, Pakistan, Oslo MET	
Web-based multi-player simulators that allow participants to take on roles as participants in the climate negotiations.	UiB	Climate Interactive	
Assessing the role of Organic value chains in enhancing food system resilience	ETH World Food System Center	ETH Zurich	Master thesis
Bio-Based Production Systems		RISE Research Institutes of Sweden & Swedish University of Agricultural Sciences	GEO-SD304
Using palaeoecology and System Dynamics to inform conservation of a biodiversity-rich, but endangered, ecosystem		University of Cape Town	GEO-SD304
Operationalizing resilience in face of climate change. The case of tomato producers in Morocco and Ghana	ETH Zurich	ETH Zurich	Master thesis
Application of systems thinking and System Dynamics to wildlife conservation	North Carolina State University	North Carolina State University	GEO-SD325

Project name	Funding source	Main collaboration partners	Student involvement
Understanding food systems in the European context: Analyses based on System Dynamics tools	KU Leuven	KU Leuven	GEO-SD304
Dynamic decision making of small-scale farmers in Ethiopia		University of Nevada at Las Vegas	Master thesis
Setting Priorities to Address the Research Gaps Between Agricultural Systems Analysis and Food Security Outcomes in Low- and Middle-income Countries	CGIAR	Radboud University (co-ordinator)	GEO-SD325
(ongoing research proposals)	NFR	Department of Information and Media Sciences, UiB	Research assistance
(ongoing research proposal)	NFR	The Norwegian Meteorological Institute; University of Oslo	
(ongoing research proposal)	UiB, NFR	Department of Biological Sciences, UiB	
(affiliate)		Center for Climate and Energy Transformation, UiB	Master theses
(affiliate)		Center for Sustainable Area Management, UiB	Master theses

Table 10: National and international collaborations – teaching

Course/ program name	Funding source	Main collaboration partners	Student involvement
Co-teaching of courses, especially GEO-310/GEO-SD310, GEO-330		Department of Geography, UiB	
Co-supervision of master students		Department of Geography, UiB	Master theses
Master's in Sustainability	Proposal stage, University of Bergen	All UiB faculties	
PhD course "PhD for innovation. Interdisciplinary problem solving and creativity"		DIGSSCORE, UiB; SLATE, UiB	Teaching assistance
European Master in System Dynamics		Radboud University, Nijmegen, NL; NOVA University, Lisbon, PT; and University of Palermo, IT	
Systems analysis MOOCs for sustainability transformation	Erasmus+	Stichting Katholieke Universiteit, Univerdisade Nova de Lisboa, University Della Svizzera Italiana, Bogazici Universitesi, Rigas Tehniska Universitate	Test pilots and ILE developments
GEO-SD321		Millennium Institute, USA	
GEO-SD309		Isee Systems, USA	
Exchange program, focus economics	SIU/DIKU	National University of Kyiv-Mohyla Academy (NaUKMA) and Ivan Franko University of Lviv in Ukraine	
Exchange program, focus public health	SIU/DIKU	University of North Dakota, USA	
Applied Methods in Agricultural and Regional Economics	ETH Zurich	Agricultural Economics and Policy Group, ETH Zurich	

5 APPENDICES

5.1 Study plan for the program

5.2 Annual self-evaluations of courses and the study program

5.3 Course evaluations

5.4 Program evaluation reports from external sensors

5.5 Letters of support regarding relevance

5.5.1 Professor John Sterman, MIT

5.5.2 Professor Michael Radzicki, Worcester Polytechnic Institute

5.5.3 Professor Bent Erik Bakken, DNV GL

5.5.4 Dr. Jack Homer, Homer Consulting

5.5.5 Dr. Hans Herren, Millennium Institute

5.5.6 Dr. Matteo Pedercini, Millennium Institute

5.5.7 Dr. Andrea Bassi, KnowlEdge SRL

5.5.8 Professor John Morecroft, London Business School

5.6 Reports 2019 to the Dean of the Social Science Faculty and the Rector of the University of Bergen


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JOHN D. STERMAN
Jay W. Forrester Professor of Management
Professor of Engineering Systems
Director, System Dynamics Group

25 May 2015

Prof. Dag Rune Olsen
Rector, University of Bergen
Dag.Olsen@mnfa.uib.no

Dear Prof. Olsen:

I write at the request of Prof. Pål Davidsen with strong support for the creation of an undergraduate program in system dynamics at the University of Bergen. Prof. Davidsen, whom I saw in Oslo this past week, indicated that he and the other members of the Bergen system dynamics faculty would be meeting with you soon to discuss this opportunity.

In short, the field of system dynamics is robust and growing; there is a shortage of well-trained individuals, at all levels (bachelors, masters and doctoral); and the program in Bergen, already one of the top programs around the world, is extremely well positioned to create a top-quality undergraduate program.

In the remainder of this letter I elaborate on these points.

The field of system dynamics is robust. Publications in top scholarly journals, the number of universities offering courses, attendance at the annual conference, membership of the professional society, and the number of corporations, government agencies, and other organizations applying system dynamics are all growing. System dynamics is increasingly applied to a wide range of management settings around the world, from business and management to public policy. The supply of qualified, well-trained individuals is not sufficient to meet the growing demand from businesses, consultancies, government agencies, and other organizations.

Originally developed at MIT in the 1950s, system dynamics is grounded in the mathematics of dynamic systems and engineering control theory. While system dynamics can be, and is, applied to physical, technical, biological, and other types of systems, it is particularly well suited for the analysis of socio-technical systems, that is, systems in which human behavior plays an important role and in which people interact with physical and technical subsystems. Such systems include organizations, businesses, markets, economies, the environment and the interactions among them. Scholars and business leaders agree that understanding complex systems and the ability to work effectively across disciplinary boundaries will be even more important in the decades to come. For example, Jeff Immelt, CEO of General Electric, stated in a 2009 speech, “I don’t know all the answers, I often don’t know how things are going to turn out. What I do know is that 21st century leaders must be systems thinkers.” The challenge facing universities is to move past slogans about systems thinking to train people to the highest standards of scientific rigor in system dynamics and related methods and at the same time developing their capabilities to collaborate across disciplinary boundaries, innovate, and bring those innovations to scale.

System dynamics is taught at a growing number of universities and colleges around the world. A few of the universities offering courses in system dynamics, besides MIT, include American University (Washington DC), Australian Graduate School of Management (Sydney), Brandeis University, Bogaziçi University (Istanbul), Boston University, Carnegie Mellon University, Chungbuk National University (S. Korea), Copenhagen Business School (Denmark), Darden School of Business (University of Virginia), Dartmouth College, Doshisha University (Japan), Fudan University (China), London Business School, London School of Economics, McGill University (Montreal), National University of Singapore, Naval Postgraduate School (USA), Portland State University (Oregon), Radboud University (Netherlands), Sharif University of Technology (Tehran), Seoul National Univ of Technology (S. Korea), State University of New York (Albany), Technical University of Delft (Netherlands), Technical University of Denmark, Texas A&M University, United States Military Academy (West Point), Universidad Nacional de Colombia, University of Bern, Universita della Svizzera Italiana, University of Illinois (Urbana-Champaign), University of Mannheim (Germany), University of Michigan, University of Nijmegen (Netherlands), University of North Carolina, University of Salford (UK), University of Southern California, University of Strathclyde (UK), University of Texas, University of Nevada (Las Vegas), Victoria University (New Zealand), Virginia Polytechnic Institute, Washington State University, Washington University (St. Louis) and Worcester Polytechnic Institute, among many others.

Numerous businesses and government agencies have used system dynamics to help them address important policy issues. Many of the world's leading consulting and research firms have used system dynamics, have system dynamics practices, or are seeking to develop them. In addition to PA Consulting, these include Bain, Booz Allen Hamilton, Boston Consulting Group, DNV GL, McKinsey and Company, Monitor, Accenture, AT Kearney, PricewaterhouseCoopers. In addition, the number of firms specializing in system dynamics modeling and software has grown. These include Pugh-Roberts Associates (which was acquired by PA Consulting), Cognitus, Decisio, iSee Systems, Lexidyne, Powersim, Ventana Systems, XJTek and many others. Government agencies increasingly use system dynamics, including the US Departments of State, Energy, Defense; Environmental Protection Agency, and others, along with their counterparts in other nations such as the UK, China, Brazil, to mention a few. The World Health Organization and US Centers for Disease Control use system dynamics extensively at senior levels, including, for example, the Global Polio Eradication Initiative (work that won the Edelman Award last year, the top prize in operations research and management science), and award-winning work in policy for chronic disease.

As a result of the growing success of the field, I am regularly contacted by consultancies, government agencies and businesses seeking to hire students with system dynamics skills. The supply is not sufficient to meet the demand. There is a clear need for additional talent in the field and the creation of academic programs to supply it. For example, this past week I spoke at DNV GL in Oslo. DNV GL is building a system dynamics program with research in energy and climate policy (among other topics), and is at present not able to attract sufficient talent.

The system dynamics program at the University of Bergen stands out as one of the top centers of system dynamics in the world. The faculty, including Prof. Davidsen, Moxnes, and Wheat, are leaders in the field and have won a variety of awards for their research and service to the field, including the Jay W. Forrester Award (won by Moxnes in 2000); the Forrester Prize is

given at most annually for the best work in the field published in the preceding five years. Your faculty have taken leadership positions in the field, including president of the international system dynamics society, key roles in the journal, System Dynamics Review, and as program chairs for the international conferences, and as chair of the Society's awards committee.

The Bergen program has been highly successful. Your faculty publish important, prize-winning work, which has appeared in many of the top academic journals. Many of the doctoral graduates have gone on to tenure-track positions in universities around the world. These Ph.D. graduates are among the emerging leaders of the field of system dynamics, and I have had the opportunity to meet and review the work of many of them, such as Drs. Arango, Bassi, Pedercini, Saleh, Sawicka, and of course David Wheat. The graduates of the master's program have taken positions in firms, consultancies, non-profit research organizations and government agencies. Several of the graduates of the program have won the Donella Meadows Award, presented annually at the International System Dynamics Conference for the best work by students. As a member of the award selection committee since the inception of the Meadows Award in 2001, I know that the competition is intense. The success of the students in the Bergen program is a testament to the quality of the training they receive. The importance and international reputation of the Bergen program is also evidenced by the number of top people in the field who have joined the group as faculty, visiting faculty and researchers, including Santiago Arrango (full Professor, Univ. of Medellin), Yaman Barlas (Full Professor and leader of the system dynamics group at Bogazici University), David Ford (now tenured at Texas A&M University), and Ali Saysel (Professor at the Institute for the Environment, Bogazici University), to name a few.

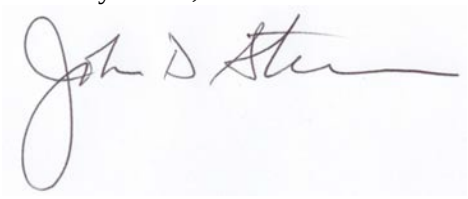
The Bergen program has been successful in attracting highly qualified applicants from around the world. The creation of an undergraduate program will be a significant step forward. The experience at MIT suggests the value of coupling undergraduate education with a robust graduate program. Over the years, the doctoral program in system dynamics at MIT has recruited many highly qualified applicants. Many of the most successful graduates, however, began their career in system dynamics while undergraduates. Students who learn about system dynamics as undergraduates can, if they choose, pursue deeper studies. The faculty of the program also have the ability to assess the capabilities of these students in depth before accepting them into graduate programs. The strong supply chain of undergraduates has generated many of the most important leaders in the field of system dynamics, dating to the beginning of the field. These undergraduate alumni include academics, such as Willard Fey (Georgia Tech, retired), Shayne Gary (Australian Graduate School of Management), and Ed Roberts (MIT), among others, and many others who have gone into business and senior policy positions. I myself was the product of the undergraduate program in system dynamics at Dartmouth College. Many of my fellow undergraduates in the Dartmouth SD program have also gone on to make important contributions in business and public policy.

The faculty of the Bergen program, with their demonstrated experience, leadership in the field, quality and impact of their research, and educational innovations (e.g. MOOCs) mean Bergen is the best place for a new undergraduate program in system dynamics in Europe and perhaps the world. I anticipate that such a program will attract many of the most talented students among

the undergraduate population, and that, in a few years, the graduates will be in high demand among employers and graduate programs in Norway and around the world.

Please don't hesitate to contact me for further information; as additional background I attach my CV for your information.

Sincerely Yours,



Jay W. Forrester Professor of Management
Professor of Engineering Systems
MIT Sloan School of Management

Copy by email: Pål Davidsen, Erling Moxnes

Michael J. Radzicki, Ph.D.
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15 October 2020

Professor Birgit Kopainsky
Department of Geography
University of Bergen
Postboks 7802
5020 Bergen, Norway

Dear Professor Kopainsky:

It is with great enthusiasm that I write this letter of support and admiration for the system dynamics program at the University of Bergen. I know the program well as I have visited Bergen many times and even delivered guest lectures to Bergen students and faculty.

Although Bergen's program is somewhat unique relative to the standard curricula offered at the world's universities, it is of enormous importance as it is one of the few places at which students can learn to be rigorous *systems thinkers*.

There are two key concepts in systems thinking. The first is that a system's structure causes its behavior and the second is that to understand its behavior a system's structure must be studied *holistically*. The later concept implies that a system's constituent parts and their interactions must be studied together, as a whole, rather than as individual entities to be examined in isolation, and whose behaviors are simply summed up to identify system-wide dynamics.

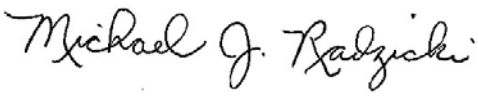
Importantly, to a large degree, *impactful leaders* are systems thinkers. For example, many key authors of the U.S. Constitution were systems thinkers. Thomas Paine, with his pamphlet *Common Sense,* helped to shift the public's focus from events (Lexington and Concord), persons (King George) and policies (taxation without representation) to a new *system* of government. Similarly great writers, novelists, and storytellers are often systems thinkers. Leo Tolstoy's *War and Peace,* for example, is chocked full of systems thinking concepts. Great leaders in team sports (e.g., point guards in basketball) are also frequently systems thinkers as they are said to be able to "see the whole court" and then distribute the ball accordingly. Finally, consider the military. The bottom of the hierarchy (in the U.S. Army anyway) is populated by "specs" – i.e., "specialists," while the top of the hierarchy is populated by "generals" - i.e., "generalists." Generals need to survey the entire battlefield and think through the interactions of the infantry, cavalry, artillery, medical corps, supply lines, etc., as well as the likely actions and reactions of the enemy.

Although impactful leaders frequently think holistically they suffer, as do all humans, from an inability to accurately think through the implications over time of their own mental models. In other words, the human mind is a poor dynamic simulator. The good news is that system dynamics computer simulation modeling can be used to address this human deficiency.

At its core, system dynamics is a technique that enables leaders to rigorously map-out the structures of the complex socio-technical-environmental-economic systems they have been chosen to lead and then reveal, via simulation, the dynamic behaviors inherent in these structures. A completed system dynamics model can be used to help redesign a complex system that is behaving poorly, create strategies, and help groups of experts and stakeholders reach a consensus on courses of action.

The University of Bergen is a world leader in the field of system dynamics and should be very proud of its accomplishments in this area. I sincerely hope that its program will be given the resources to grow and prosper as it continues to train society's future impactful leaders.

Sincerely,



DNV·GL

To whom it may concern

DNV GL
Group Technology and Research
Veritasveien 1
1322 Høvik
Norway

Tel: +47 926 53 104

Date: Oct 19, 2020

Our reference: B E Bakken

Relevance of the UiB Master programs in System Dynamics

DNV GL, a global risk management and certification organization with 12000 employees in 100 countries, has built up a System Dynamics Group within its corporate research unit. This unit has enabled investigations in the world's grand challenges, such as climate change, energy transition, and the fate of the ocean. The System Dynamics approach has enabled our organization, with limited resources, to build up world class competence in new areas in a very short time. As an example, our annual "Energy Transition Outlook" covers the same issues as the Paris based IEA "World Energy Outlook". Yet their staff is ten times bigger than ours of six, while their forecasting accuracy appears no better. Also in consulting assignments, such expertise has enabled us to win important contracts, benefitting corporate and NGO customers in Norway and elsewhere.

System Dynamics expertise is hard to obtain. It requires a rigorous scientific training. UiB has over the last decades built up a very successful graduate degree program in System Dynamics. We have found that UiBs graduate degree programs deliver high calibre graduates. We have been fortunate enough that most of our hirings have come from graduates with education from UiB's System Dynamics programs. Moreever, we have also hired consultants with degrees from its programs.

In my estimate, the System Dynamics approach is extremely and increasingly valuable in a world where interconnections and feedback within and between sectors cannot be left out. Moreover, the role of computer simulation of complex socio-technico-economic systems is also becoming mainstream. I am hopeful that the UiB graduate degree programs with its core staff will continue to afford the world with high calibre professionals also in the future: The world and especially professional service firms need them.

Do not hesitate to reach out to me for further detailing.

Sincerely
For DNV GL

Professor Bent Erik Bakken, Ph D (MIT '94)
Deputy Program Director
Energy Transition Research

Homer Consulting

H_C

13 October 2020

Re: Master Program at Universitetet i Bergen in System Dynamics (Department of Geography)

As an expert practitioner of system dynamics for the past 40 years (www.homerconsulting.com), I would like to comment on the relevance of UiB's Master program in System Dynamics. I was already familiar with the many excellent graduates of the program, having met them over the years at conferences and through professional interactions. Now I have had a chance to review the entire list of thesis topics from 2011 to the present, and I am even more impressed with the significance of the program and how it prepares students to become professionals in the field. The coursework covers modeling methodology and applications, policy analysis and design, and natural resource management, all topics central to work in the field. The student becomes adept at modeling and its conceptual and technical intricacies, and then works closely with a supervisor to research and do original modeling on a relevant topic of their choice. Over the years, the thesis topics have run the full gamut of business applications, public policy applications, and methodological advances. I cannot imagine a two-year program that is more focused on what students really need to learn, both in the classroom and experientially, to prepare them to become professionals in the field of system dynamics.

Sincerely,
Jack Homer, PhD.

Jack B. Homer
72 Station Hill Road, Barrytown, NY 12507
Telephone (609) 680-7287
e-mail: jack@homerconsulting.com

MILLENNIUM INSTITUTE

Alice Kaufman
Chair, Board of Trustees

Hans R. Herren, Ph.D.
President

Christine Harada
Treasurer, Board of Trustees

Washington, October 15, 2020

To whom it may cioncern

UiB's SD Program Relevance to the field of Sustainable Development

System Dynamics and Sustainable Development are two highly intertwined fields. Since the early 70s, it was clear how the seminal work of Jay Forrester and his team at MIT provided a quantitative foundation for much of the following global sustainability research. The ability to jointly simulate and analyze the dynamics of growth and depletion of natural resources that System Dynamics provides is essential to understand our sustainability challenges and identify effective solutions.

The University of Bergen (UiB) provides excellent education and formal training in the field of System Dynamics, including its application to the field of Sustainable Development. At the Millennium Institute, our mission is to spread the use of systemic, quantitative tools to support Sustainable Development, and we make heavy use of System Dynamics modeling. Over the last 15 years, most of our technical staff have received formal training from UiB's program, which we consider essential to operate in this field. We have also observed how the demand for that type of knowledge and skills has been gradually increasing also in other organizations in our field, including UN bodies and other international organizations.

I believe that the education provided by UiB's System Dynamics program will be ever more fundamental in the coming years, to those who will be addressing the most pressing global sustainability challenges.

Hans R Herren, PhD
President Millennium Institute

A nonprofit organization promoting long-term integrated global thinking

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UiB's SD Program Relevance

For over 15 years, I have had the privilege of guiding graduate students in their discovery of the complex dynamics underlying global development processes. System Dynamics modeling is the most central analytical tool in our toolbox, offering insights into those dynamics that only a proper systemic, quantitative analysis can provide. Driven by their curiosity, students gradually develop System Dynamics skills out of necessity, building up a library of techniques that they then carry to their professional activities.
As a teacher, it is rewarding to accompany students in this journey, which often involves putting into question their pre-conceived mental models, and observe how their thinking gradually evolves. Besides the specific technical knowledge, such change in their thinking influences their progress in their professional and personal life. The rigorous application of the scientific method coupled with adopting a broad, systemic perspective provides students with a privileged perspective on complex issues, that is highly relevant in all problem-solving related positions, as the career of our alumni in the most disparate fields indicates.

Matteo Pedercini
VP and COO
Millennium Institute
Washington D.C.

KnowlEdge Srl www.ke-srl.com

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To whom it may concern,

I have attended the Master program in System Dynamics offered by the University of Bergen during 2004-2006, to then proceed with the completion of a Ph.D. in 2009.

My assessment of the programs and courses provided is very positive. In the field of System Dynamics (SD) the quality of teaching and materials are unmatched. There are many courses teaching SD worldwide, some of which I have attended (in Italy and Spain) before arriving in Bergen, but these are short courses within Master programs. UiB offers a full-time SD Master and Ph.D. program that prepares students for a career in this field. To date, no other university worldwide offers such a strong and complete program.

The teachers were outstanding, offering a good balance of research and practical applications. In addition to having a faculty that is very prepared, recognized and appreciated in the field and beyond, the study environment in Bergen, with small classes (up to 20-25 students each year), is perfect for ensuring effective assimilation of knowledge.

The facilities are also excellent and opportunities to apply this modeling methodology to real world problems abound thanks to the experience of the teaching staff and collaborations with practitioners (e.g. Millennium Institute).

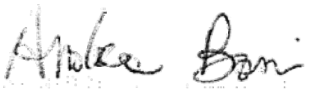
In addition to the quality of courses in System Dynamics offered at UiB, I want to emphasize the potential career path that becomes available to UiB alumni. In my case, the M.Phil. opened a series of new opportunities, leading to 15 years and counting of work in the field of System Dynamics to inform policymaking for sustainability. Over time I have realized that UiB equipped me with a very solid basis of knowledge, which allowed me to work in innovative areas for policymaking (e.g. green economy, green growth, circular economy, climate adaptation and mitigation), with more than 30 governments and with several and very influential international organizations. I have also published more than 30 papers in peer-reviewed journals, contributing to advancing the state of knowledge in several fields. In summary, UiB and the SD program have allowed me to have an impact on science, decision making and effectively support sustainability worldwide.

I can also indicate that I am not the only alumni that profited from the SD program at UiB in my cohort. Several of my classmates developed a career in the field, both academic or in the consulting world.

Further, UiB has been an anchor for the field in the past 20 years. In my personal experience I can say that the SD group at UiB has been instrumental in supporting the creation of the SD Chapter of the System Dynamics Society in South Africa. This is a process I started 12 years ago, and it ended up being a success primarily thanks to the possibility for researcher in South Africa to attend SD courses at UiB.

I cannot stress enough how important the SD program at UiB is, especially for the growing impact this methodology is having for sustainability science and for sustainability-oriented policymaking worldwide.

Best regards,



Andrea M. Bassi

Founder and CEO, KnowlEdge Srl

27/10/2020

To Whom It May Concern

I am writing this letter in support of the master program in system dynamics at the University of Bergen. Let me begin with some biographical notes. My academic career in system dynamics and simulation spans more than forty years - first at MIT Sloan and then at London Business School. I am currently a Senior Fellow in Management Science and Operations at London Business School. I have visited the University of Bergen on several occasions in the past. In 1994 I was a member of an external review panel to evaluate Bergen's fledgling system dynamics program. I subsequently attended academic events organized by Bergen faculty and held on campus, including the International System Dynamics Conference in 2000.

Importance and Relevance of Bergen's Master Program in System Dynamics

Bergen's 2-year master program in system dynamics offers students in-depth training in all aspects of the subject. The program is delivered by a strong and internationally recognized academic team. Moreover, Bergen has become a lead partner in the Erasmus-funded European Master's Program in system dynamics.

Nowadays university level courses on simulation modelling are widespread, typically covering the core conceptual and technical aspects of model building. However, Bergen's program goes much further by developing students' expertise to engage with model users and to clearly articulate model-based insights. These communication skills are vital for modelling projects if they are to achieve real-world impact.

Competent simulation modellers are valued in business and society. The Covid-19 pandemic has demonstrated to all of us (policy makers and the public-at-large) just how important simulation studies are for understanding and managing the puzzling dynamics of unfolding futures. The skills to conduct such studies take time and serious effort to acquire. Bergen's program provides the necessary depth and breadth. There are four semesters of integrated study and practice. Semesters 1 and 2, in year 1, cover the fundamentals of system dynamics modelling from conceptualization to equation formulation, model-based analysis and policy design. There are six courses in these two semesters - a full immersion in the approach that is essential for students to build credible, client-oriented models and to persuasively interpret the results. There are also options to examine special topics in policy, applications and methodology. Year 2 builds on this solid foundation with courses that hone effective model-based communication (such as the writing of project reports and the design of learning environments) culminating in a thesis project spanning the final semester.

Exemplary Student Work

Over the years I have encountered several students from the Bergen program and seen examples of their thesis projects. They have conducted good applied research that satisfies what I look for in terms of model quality and practical relevance. The work compares favourably with models and project reports I have evaluated from graduate students at London Business School, MIT Sloan, the University of Stuttgart, TU Delft and Worcester Polytechnic Institute. Similar favourable comparisons can be drawn among student talks at international conferences of the System Dynamics Society. For example, just this year I joined a Zoom presentation by Ema Gusheva based on her master thesis in sustainability and rule compliance in public forests. The presentation was part of the Society's 2020 online conference hosted by the University of Bergen. Ema talked enthusiastically and persuasively about her compact system dynamics model of the logging industry and the simulation experiments she conducted on the decision making and compliance of loggers. The 110-page thesis itself (which I have seen) is well-written and shows a mastery of essential modelling skills and related literature,

with results of practical relevance to both loggers and policy makers. Back in 2016 I met Omar Chique, a doctoral student at Bergen whose knowledge of system dynamics had come from the suite of courses in the Bergen masters. He was on a trip to London and stopped-by my office at London Business School for a chat. He told me of his work to develop a system dynamics model of OPEC and the oil industry. I myself have conducted model-based research on the global oil industry, in collaboration with Royal-Dutch Shell. So I was curious to hear what he would have to say. We talked for a couple of hours about the upstream oil producers and decision making in OPEC. I recall being impressed with his grasp of industry operations, gleaned from background reading and conversations with OPEC delegates, synthesized through the discipline of formulating a credible simulation model.

Conclusion

Both my examples illustrate the importance of the Bergen program to train proficient modellers with the knowhow and confidence to build simulation models of practical use and relevance. Since I first visited Bergen in 1994 some 300 master and PhD candidates have graduated from the program. Many have carried their modelling skills to careers in the public and private sector. Others have moved into academic life or joined specialist consulting and software firms. This sustained multi-decade output of good modellers is a significant accomplishment and has also contributed to the growth of the field. Long may it continue.

Dr John Morecroft | Senior Fellow | Management Science and Operations

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www.wiley.com/go/strategicmodelling2e

Plan for the System Dynamics Group, Faculty of Social Sciences, University of Bergen 2020 – 2030

August 20, 2019

UNIVERSITY OF BERGEN

PREFACE

We appreciate the invitation to present a long-term plan for the Group for System Dynamics (GSD).

The plan reflects:

- an increasing demand for interdisciplinary systems analysis concerning sustainable development;
- the strategy documents for UiB and the SV-faculty;
- the rectorate's expressed interest in System Dynamics in connection with interdisciplinary education regarding sustainable development, research regrading sustainable development goals (SDGs), and the establishment of an Honours program at UiB; and
- the Dean's desire to establish a stronger integration between the System Dynamics Group and the departments of the SV-faculty.

As will be discussed in section 4, if cooperation across departments and faculty and innovative education are both of the essence, then the System Dynamics Group would recommend an Honors program that yields the most efficient use of the current course portfolio.

The plan:

- builds on our existing Bergen and EMSD master programs in System Dynamics;
- shows how the existing programs can become the backbone of an interdisciplinary master program in sustainable development; and
- shows how a master program in sustainable development can be facilitated and strengthened if supported by interdisciplinary bachelor level education in sustainable development.

1 INTRODUCTION

The System Dynamics Group (Gruppen for systemdynamikk - GSD) originated from education and research conducted at the Department of Information Science. In recognition of the significance of the field and of its prominence at the University of Bergen, the university conferred upon its founder, Prof. Jay W. Forrester, an Honorary Doctorate Degree as early as in 1990. In 1995 an international Master´s- and Ph D program in system dynamics was established at the initiative of the university leadership under the that same department.

As of 2004, the System Dynamics Group has been organized as an economically autonomous unit under the Faculty of Social Sciences and has been administrated as part of the Department of Geography. Currently the GSD is furnished with 3 Full Professors and 16 Ph D Candidates.

The GSD is the most prominent center for system dynamics education and research in Europe and is considered, in many respects, on par with the corresponding group at MIT.

During the time period 2003 – 2020, four of the GSD employees will have held the precedency (and a number of other offices) of the international System Dynamics Society, - this includes the first female president. Two of its employees have received, respectively, the Jay W. Forrester Award and the SDS Distinguished Service Award. A number of students have, over the years, been awarded the Donella Meadows Award for the best student work.

Internationally, the labor market for system dynamicists is favorable. There is demand for candidates with competence in comprehensive, integrated analysis of complex systems and in the development and assessment of policies that cut across disciplines as well as socio-economic sectors. E.g. the EU calls for these kinds of skills in a number of its policy documents specifically pertaining to the Sustainable Development Goals (SDGs). Moreover, the Council for Science and Technology, UK Government Office of Science calls, in its report “Computational Modeling: Technological Futures”, 2018, for competence in modeling and analysis with an explicit reference to system dynamics. Moreover, in the 2017 report "Working with change: systems approaches to public sector challenges", OECD summarized the challenges as follows:

Box 1: OECD statement on public sector challenges

> Governments that have spent decades perfecting systems that can successfully manage complicated problems (such as banking regulation, trade treaties, and healthcare systems), now find themselves immersed in a world of complex problems. -- Traditional management tools have limited capabilities when applied to complex problems. For the sake of expediency, manageability, and clarity, traditional approaches simplify complex problems into what are considered to be its constituent parts and manage them through discrete interventions, layered one on top of another. However, by looking at actors and interventions in isolation or disconnected from past efforts, complex policy legacies may fail to be

captured and addressed. -- Applying a systemic lens to complex problems is useful to map the dynamic of the system underpinning it, how the relationship between system components affect its functioning, and what interventions can lead to better results. System thinking help understand how systems are structured and how they operate.

Similar demands for systems analysis have been voiced by WHO and UNEP.

Tracer studies document that 65% of our Ph D candidates hold prominent teaching or research positions in HEIs (see Attachment 1), - and about 40% of our former EMSD Master´s students have been recruited to positions in academic institutions. A significant number of our regular Master´s candidates have earned their PhD degrees in foreign institutions and currently hold professorships at universities across the world.

The role that system dynamics plays as an interdisciplinary method applied across socio-economic sectors is well-documented in the papers published by the academics and practitioners of the field (see e.g. System Dynamics Review and the annual Proceedings of the System Dynamics Conference). Moreover, it is illustrated by the publications of members of the GSD in prominent journals e.g. in management (*Management Science*), political science (*Journal of Conflict Resolution)*, economics (*Journal of Environmental Economics and Management*), medicine (*Drug and Alcohol Dependence),* education *(Journal of Applied Research in Higher education),* as well as in system dynamics (*System Dynamics Review*)

In the plan that follows, we outline, in section 2, how the research and education programs of the GSD are aligned with societal needs and the strategy of the University of Bergen and the Faculty of Social Sciences. In section 3, we describe our plans for research on system dynamics, SDGs, and digital education, for international research collaboration and for funding. In section 4 we describe our educational program plan, alternative options, digital outreach, international partners, and funding opportunities. In section 5 we outline our initiatives and plans for continued collaboration within the Faculty of Social Science and with faculties beyond. In Section 6 we outline the resource requirements associated with our plans.

2 SYSTEM DYNAMICS: ANALYSIS OF SDGS AND COMPLIANCE WITH THE STRATEGY OF THE UNIVERSITY AND THE FACULTY

2.1 The System Dynamics method

System dynamics is the study of complex systems by means of computer-based modeling and simulation. These systems are ubiquitous and transboundary, - they transcend social sectors and scientific disciplines. The structure of such systems encompasses non-linearly coupled causal feedback loops that are characterized by time consuming processes (delays) and stochasticity. Such structures produce dynamic developments over time (including chaos) that do not easily lend themselves to interpretation or, even less so, to management. Such studies are typically threefold:

1. We need to understand the dynamic development that complex systems exhibit over time. Specifically, we study dynamics associated with challenges we face, and seek to understand the nature and the structural origin of such dynamics.
2. We need to facilitate strategy development and policy design, i.e. structural modifications governing decision making so as to cause systems to embark on a favorable rather than an unfavorable dynamic development. We test policies in the very same models that we use to analyze the origin of problematic dynamics.
3. We need to disseminate systems insights among students and stakeholders, including strategy developers, policy designers, decision makers and the public at large, so as to promote systems understanding and facilitate good systems governance. We do so, making use of digital learning technologies.

Our research and education focus on theories, methods, techniques, and tools aimed at addressing these needs. This includes e.g.;

1. data collection, modeling, statistical parametric and non-parametric estimation and interpretation, surveys and conjoint analyses, synthetic data analysis, machine learning, model-based decision-lab experimentation, “big-data”-based model identification, group model building, community-based modeling, Monte-Carlo and sensitivity analysis, feedback loops dominance analysis (such as gain, eigenvalue, pathway participation, and link and loop score analyses), agent-based modeling;
2. dynamic control analysis, policy optimization in stochastic domains, and stakeholder involvement; and
3. multi-user interactive learning environment technologies (ILEs embedded in MOOCs), - originating from learning-theory, stock and flow diagrams, the associated use of graphics, animation and gaming, and learning analytics.

System dynamics is operational and problem-oriented. A general characterization of the kinds of problems addressed using system dynamics is offered in Attachment 1.

2.2 Applying system dynamics to attain the SDGs

In response to a call from Rector Dag Rune Olsen, the System Dynamics Group prepared, May 15. 2019, the attached report (Attachment 4) on the relevance of system dynamics to comprehensive, integrated studies of goal attainment across the Agenda 2030 SDGs. In that report, we outline what makes system dynamics a method tailored to the study of sustainable development across the SDGs. We refer to 24 ongoing research projects conducted by the group that is of relevance to this theme. Two of these projects are Horizon 2020 projects and one is conducted in collaboration with UNEP ("African Coexistence Landscapes") and is funded as a Strategic Program by the EU. Moreover, we outline 3 EU proposals and 1 Belmont Forum proposal, all SDG-oriented, that are in the pipeline (to be submitted Jan / Feb 2020).

Using system dynamics, we specifically analyze the *interaction*, i.e. synergies to be taken advantage of and conflicts to be avoided, between policies designed to facilitate the attainment of goals in a variety of sectors (including health, education, resource utilization, climate change, energy, and the economy).

Our purpose is to empower stakeholders that are intent on contributing to a comprehensive attainment of the SDGs. We do so by educating them in participatory modeling, simulation, and analysis. By way of such a process (often called Group Model Building (GMB) or Community Based System Dynamics), coherent models are being developed that are tested for consistency and transparency. Thus, stakeholders identify with, build appreciation for, and take ownership of these models. This increases the likelihood that the managerial conclusions reached, i.e. strategies developed and policies designed, are actually being implemented and followed up over time. Consequently, the research and education offered by the GSD focus on participatory modeling involving stakeholders at all levels of governance, in a variety of sectors and across relevant disciplines, so as to facilitate sustainable governance in the long-term.

In many organizations, such as governing bodies at all levels, that serve as custodians of the SDGs, there is a significant personnel turn-over. As people come and go, the challenge is to retain the experience gained over time. Since the effects of strategy development, policy design and even decision making play out over very long periods of time, linking those effects back in time to their origin, is remarkably difficult. It is, however, very important to do so, and here is why: If, at some point in time, one comes to realize that a system under management develops differently than intended, one must ask what "went wrong". We must identify the problem, - i.e. the structure underlying such an unintended systems behavior. Based on the answer, there may be calls for changes in strategies and policies

under which the system is managed. What "went wrong" is commonly that the prevailing strategy and policies were formed based on a limited understanding of the system at hand, - i.e. on systems misperceptions. Consequently, it makes sense to compare the knowledge held at the time with our current systems understanding. Typically, this is demanding because the assumptions upon which strategies, policies, and decision were made, are seldom being recorded or are lost in the meantime - very often as a result of organizational turn-over. System dynamics offers a way to address this challenge: A model is a knowledge repository. It records the knowledge, at the time, upon which managerial actions were taken.

Developing such a model should, consequently, be an on-going, gradual improvement process, not a one-time event. Regularly, a comparison should be made between the dynamic development of a system and predictions made, based on an earlier version of a systems model. Such a comparison invariably results in the conclusion that there is still something that we do not understand about the system we manage. If the discrepancy identified is significant, then it motivates and informs a learning process: What is it about reality that we have not yet successfully captured in earlier versions of the model and that should form the basis for an improved management, - what have we learned? In short, system dynamics, used this way, becomes a vehicle for organizational learning. Coherence and consistency are ensured in the course of this process by (a) expressing our insights over time in the same language across sectors and disciplines, (b) engaging in a gradual improvement of the model, and (c) comparing the simulation results generated by previous models with those generated by more recent versions. If put in place, such a gradually improvement of a formally recorded, dynamic repository of knowledge, will remain less affected by organizational turbulence and may thus facilitate a robust "organizational learning" process. This extends to societies at large and to local communities in particular. Consequently, the research and education offered by the GSD focus on a resilient use of models over time so as to promote "*organizational and community learning"* and facilitate sustainable governance in the long-term.

We recognize that, fundamentally, learning takes place at an individual level. Our research demonstrates that learners gain deep and rich insights when exposed to models of complex, dynamic systems. Learning can be promoted by interactive learning environments (ILEs) that allow learners of all sorts[1] to experience the consequences of their actions in decision labs. Using our MOOCs, we can reach learners that are the most in need of SDG empowerment all across the globe.

The demand for system dynamics based SDG competence is illustrated by the justification for our Marie S. Curie proposal to the EU (SDG IMPACT) (Attachment 4 in the Report to

[1] E.g students and stakeholders such as strategy developers, policy designers, decision makers, and the public at large.

Rector, May 15. 2019), where the application of system dynamics to the analysis across clusters of SDGs is synergized with its application to the development of interactive learning environments (in MOOCs) for the purpose of knowledge dissemination.

2.3 Compliance with the strategies of the University of Bergen and the Faculty of Social Sciences

Both the University of Bergen and the Faculty of Social Sciences subscribe, in their strategy documents, to a comprehensive attainment of the Sustainable Development Goals (SDGs) as outlined in the Agenda 2030. There is a particular focus on climate, energy, the marine environment, health, governance, and welfare. All of these domains exhibit complex dynamics that calls for advanced analyses. The Faculty of Social Science calls specifically for the development and use of innovative interdisciplinary theories and methods.

The analysis of time-consuming, non-linear feedback processes commonly defies our cognitive capabilities as well as an effective application of analytical methods, techniques, and tools such as mathematics and statistics. Thus, there is need for approaches that bridge the gap from qualitative to quantitative approaches and that facilitates an effective application of model-based experimental techniques by way of numerical analysis, - say simulation. By means of its digital techniques and tools, system dynamics offers a method to meet these needs.

In its quest for solutions, the university calls for operational approaches aimed at problem solving. As outlined, system dynamics is operational, takes a dynamic development that poses a challenge (problem) as a point of departure and is employed to identify a long-term strategy of well-balanced policies intended to govern decision making to address the challenge at hand.

Both the university and the faculty have, in their strategies, emphasized the significance of innovative research on and the development and delivery of education on digital platforms. Based on the pioneering work at UiB, chaired by members of the system dynamics group both in the field of educational information science and at the Center for Educational Information Science and Technology (EIST)[2], and its wide network of educational technology specialists in academia and the private sector, the group has spearheaded the development of model-based interactive learning environments (ILEs) and the delivery of educational material by way of flipped classrooms, peer instruction and learner directed learning both in

[2] Pål I. Davidsen was appointed the first professor of Educational Information Science at the university of Bergen and established and chaired the research center EIST for 5 years and the same time as he chaired a corresponding center at the University of Karlstad, Sweden.

the form of its off- and on-campus education (e.g. by way of MOOCs)[3]. Perhaps just as important, the GSD educate Master´s and Ph D candidates in the development and application of these learning principles and technologies, in the effective delivery of web-based learning material, and in the assessment of both the technology and its application[4]. Finally, we employ interactive learning environments in our empirical laboratory studies of decision makers in order to analyze their understanding and decision-making (policies) in the face of complex, dynamic tasks. By embedding policies identified that way in models of real systems (e.g. energy markets), we can explain inefficiencies in such systems that are caused by misperceptions held by decision makers. And we can develop ways to mitigate such misperceptions to improve decision-making. Consequently, the research and education offered by the GSD focus on model- and simulation-based educational technology, i.e. digital educational technology, including multi-user interactive learning environments (e.g. games), and its use in a variety of domains of application, e.g. in experimental, behavioral economics.

It is the strategy of the University of Bergen as well as the Faculty of Social Sciences to take on a prominent role on the international academic arena. This is true for research as well as education. GSD is the most prominent center for system dynamics education and research in Europe and, arguably, on a world basis. Historically (since 1995), 4 of its 6 professors have been foreigners, - and no less than 98% of our students likewise.

In terms of research, as indicated in the introduction, the System Dynamics Group has published internationally in a variety of reputable international journals in a wide variety of research domains. Moreover, as documented in the report to Rector (Attachment 2), the group participates over and beyond its capacity in a significant number of international research project, - that are, predominantly, of relevance to the SDGs and funded by EU.

In terms of education, both the university and the faculty emphasize the need for English as a language of instruction, for a significant inflow of foreign students, and for a corresponding exchange of native students with partner HEIs.

The system dynamics program is unique in the sense that there exist no corresponding combination of Master´s and PhD education worldwide. The program was originally established as an international program serving merely foreign students. The language of instruction has always been English, and the program was only opened to Norwegians as late as in 2000. Of the well over 300 graduates, nearly all have been foreigners. Consequently, the program has contributed significantly to the recruitment of foreign UiB students targeting the Faculty of Social Sciences, and it will continue to do so.

[3] The MOOC in Natural Resource Management, developed by Erling Moxnes in collaboration with Prof. Stephen Alessi at Ohio University, was the first of its kind in Norway.

[4] In 2019, two of our PhD candidates received prized at the System Dynamics Conference for their pioneering research in this field.

Over the last 12 years, we have also offered, in collaboration with three European universities[5] a European Master´s in System Dynamics (EMSD) from which well over 200 students have graduated. For 9 years this education was funded by the EU and recognized as an Erasmus Mundus program. It has regularly been reassessed and found worthy of financing as being among the best educational master´s programs in Europe[6].

The GSD offers a local PhD program. Also, it offers a PhD program jointly in the form of double degree programs with the University of Palermo and with the National University of Kyiv-Mohyla Academy (NaUKMA) in Ukraine.

SIU / DIKU has, for a number of years, financed an extensive exchange of master´s and PhD students as well as faculty with the NaUKMA and the National University of Lviv in Ukraine as well as the University of North Dakota (UND), USA.

The NGO Millennium Institute, a close partner of the GSD, has annually, for the last 12 years, recruited public governmental officials to our GEO-SD 321 course in Model-based National Development Planning. They originate from nations in the developing world, predominantly Africa, and are trained to apply the system dynamics model Threshold 21 to comprehensive development planning with a focus on SDGs. Since the 1990´ies, the Millennium Institute has been undertaking well over 50 model-based national development projects based on the system dynamics method and was, in 2017, awarded the Best Practitioner´s Price by the System Dynamics Society.

In conclusion, and true to its original UiB charter, the System Dynamics Group is an internationally oriented academic entity with an agenda to serve the wider community of researchers and practitioners worldwide with the knowledge and skills to professionally conduct research, offer education, and exercise management, in complex, dynamic domains and to undertake model-based knowledge dissemination to a wide variety of audiences worldwide. As documented, the main emphasis has been on the application of system dynamics to the SDGs.

[5] Radboud University, Nijmegen, NL, NOVO University, Lisbon, PT, and University of Palermo, IT.

[6] As part of the evaluation and Erasmus Mundus accreditation process, the EMSD program has been evaluated regularly by the European Commission and was one of the few programs that received an extended funding for an additional 4 years. We are currently in the process of resubmitting an application for additional Erasmus Mundus funding.

3 THE RESEARCH AND DEVELOPMENT PLAN

3.1 Introduction

In this section we describe the plans for research and development undertaken by the System Dynamics Group. Moreover, we outline our plans for international collaboration and for funding. The System Dynamics Group conducts research in three main areas. In 3.2 we describe our plans for basic research and development in the field of system dynamics. In section 3.3 we describe plans for our application of system dynamics to global sustainable development. In section 3.4, we describe research and development in the field of interactive learning environments and their application in experimental sciences and well as in the delivery of education my means of MOOCs.

The research activity of the System Dynamics Group is extensive and we hosted by the beginning of this year 16 Ph D candidates (Attachment 1). Last year, 3 candidates graduated from that program, and we expect the rate of graduation to be no less in the years to come.

3.2 System Dynamics theory, methods, techniques and tools

Analysis of dynamic systems is complicated and has traditionally been carried out based on time-consuming methods. We want to contribute to automated analysis, where the importance of model parts and of feedback loops show up in diagrams during simulations. This new tool builds on eigenvalue analysis and pathway participation metrics. The project is funded by the company isee Systems in the US.

Optimization in stochastic, dynamic systems is complicated. Traditional methods such as stochastic dynamic programming requires model simplification to find solutions. Measurement stochastics are particularly demand since the they imply an expanding state space. Using stochastic optimization in policy space (SOPS), we have been able to find optimal policies also for the case of measurement error. Our software has now been implemented in isee Systems simulation software Stella Architect. We have previously made use of SOPS to solve fishery and engineering problems, and have ambitions to use SOPS to deal with SDG problems involving uncertainty.

Delays cause problems for regression analysis. Using the standard Koyck lag formulation in econometrics, estimated adjustment times are biased. We want to develop an alternative formulation that involves a nonlinear formulation that can be estimated using the built in tool for regressions in Stella Architect.

In a collaboration with HelseVest, we use synthetic data analysis to test the goodness of statistical investigations related to Alzheimer's disease. This type of analysis can also be carried out in Stella Architect, and can be used to check the goodness of statistical analysis in complex domains.

The advanced course in system dynamics, mentions several other methods that we employ and adapt to dynamic systems, see Section 4.2.2.2.

3.3 Applications of System Dynamics to sustainable development

We have already described how System Dynamics can contribute to SDG research. A full report on our 25 ongoing research projects on the application of system dynamics to sustainable development was presented to the UiB Rector May 15., 2019 (Attachment 4).

Suffice to say, three of these projects are funded by the EU and are conducted in close collaboration with a variety of international partners, including the UN.

The System Dynamics Group is planning to collaborate on research with five groups of partners;

- higher Educational Institutions (HEIs) abroad, such as the current EMSD, Marie Curie, Erasmus, and Horizon 2020 partners;
- international organizations, such as UN and its agencies (e.g. UNEP, WHO, FAO), EU (ERCs), and NRC;
- NGOs, such as Millennium Institute and Climate Interactive;
- private consultancies on sustainable development, such as KnowlEdge srl., and technology developers, such as isee Systems; and
- stakeholders in local communities and representatives of national agencies aiming for a sustainable development.

The group will continue to develop research and educational proposals to aggressively seek funding locally, nationally, within EU, and among international agencies.

It will do so in the spirit of the nature, quality, and scope of the international partnerships we form, so as to increase the probability of success.

3.4 Interactive Learning Environments and MOOCs

For about 25 years, the System Dynamics Group has conducted research-based development and application of model-based interactive learning environments. The pioneering research by the GSD has significantly influenced the development of commercial software such as Powersim, Smia, and Stella Architect and favored the digitization of the educational program

in system dynamics offer by UiB. As a consequence, market leading Stella Architect currently supports the development of web-based interactive learning environments by way of a seamless transition from modelling and simulation to interface design.

Encouraged by the UiB emphasis on digitized education and web-based distance learning, the System Dynamics Groups plans to continue and extend its research and development efforts with regards to such model-based learning environments.

Interactive learning environments are being developed in a variety of forms, two of which are most common:

- interactive “textbooks” or MOOCs in which simulators and games are embedded and where learners are guided through the textbook conditioned by how well they perform; and
- serious gaming platforms, developed to support single- as well as multi-user activities and aimed at training of strategy developers, policy designers and decision makers.

A body of knowledge articulated in a wide variety of learning theories supports the development, assessment, and use of such learning environments.

While MOOCs are used in the education offered by the System Dynamics Group, the gaming platforms are commonly used in experimental sciences (economics, psychology etc.). This research has been followed up by the GSD and, using its cutting-edge technology, GSD has opened up an important avenue into research in experimental science applied to complex, dynamic domains. Through the investments the GSD has made in developing and implementing cutting edge technology for laboratory experiments, the development time for such experiment has been reduced to less than 10% of what it used to be five years ago.

Finally, we work with the NGO Climate Interactive to enable online gaming with their climate model C-ROADS, which is a model that has been used at COPs, New York Times and other media. We are now offered to work with Climate Interactive to use their energy-climate model En-Roads for research and education, a project that will be of great use also for CET and our SDG education.

4 THE EDUCATION PLAN

4.1 Introduction

In this section we describe our plans for education. In 4.2.1 we describe the current Master´s degree Program in System Dynamics. In 4.2.2 we describe how we may utilize the Master´s degree Program in System Dynamics as a foundation in a graduate program in sustainable development, and we outline the administrative challenges in doing so. In 4.2.4 we describe how the challenges described in 4.2.2 may be met by establishing a combined Bachelor´s and Master´s Degree Program in Sustainable Development. Finally, in 4.2.4 we discuss how the current GSD course portfolio may, with a minimum of effort, constitute the backbone in an Honors Degree Program.

In 4.3 we outline our activities and plans for digital outreach, international collaboration, and external funding, a major effort on part of the GSD both in terms of research, development and education.

4.2 Education programs

4.2.1 The current Master's program

The System Dynamics Group currently offers and *will continue to offer* internationally recognized graduate education in system dynamics at the Master´s and Ph D level.

There is the local master´s degree program (the Bergen Master´s Program in System Dynamics) and the European Master´s Degree Program in System Dynamics (the EMSD[7] Program) offered in collaboration with 3 other European Universities. In addition, the GSD annually hosts;

- students from Ukraine and the USA visiting by way of our DIKU exchange programs;
- a variety of PhD students, enrolled in partner universities, who take our graduate courses and who want to use System Dynamics in their theses; and
- public planners from development countries, recruited by our long-term NGO-partner Millennium Institute, D.C, USA.

Both Master´s programs offer the qualifications required for a master´s degree in the field of system dynamics. Each program spans 4 semesters and yields 120 ECTS credits. 3 semesters are devoted to coursework (9 courses, 10 ECTS each). The 4th semester is devoted to super-

[7] According to EU: "An Erasmus Mundus Joint Master Degree (EMJMD), is a prestigious, integrated, international study programme, jointly delivered by an international consortium of higher education institutions."

vised thesis work. In addition, special topics courses (research seminars, each 10 ECTS credits) may be offered in special cases. The structure of the program is as follows:

Semester 1

3 foundation courses in modeling and analysis (GEO-SD 302, 303 and 304). These courses are the ones taken by all Bergen and EMSD students and by most of our guest students.

Semester 2

3 courses focusing on the application of system dynamics to the SDG domain, i.e. to;

- GEO-SD 308; *Policy design and implementation*;
- GEO-SD 321; *Model-based socio-economic planning*, - in collaboration with Millennium Institute); and
- GEO-SD 325; *Client-based modeling projects*, - in collaboration with international partner institutions UNEP, WWF, NRC, MI, and Climate Interactive.

Semester 3

3 courses focusing on outreach design and applications and on master thesis preparations;

- GEO-SD 309; *Model-based interactive learning environment (ILE) design*, - implementation and assessment (typically applied to web-based multi-user games);
- GEO-SD 330/660; *Natural resources management*;
    - taught by way of an ILE-based MOOC;
    - offered globally each semester and attracting a considerable number of students at UiB as well as abroad;
    - serving as an important recruitment initiative.
- GEO-SD 310; *Writing course and project description* in collaboration with Department of Geography.

Semester 4

Master thesis

4.2.2 Option I: Master´s Program in sustainable development, built on the System Dynamics master

Option I is to continue offering the existing Master´s Programs in System Dynamics and to utilized more extensively the existing *option* for students to specialize in SDGs in collaboration with departments at the Faculty of Social Sciences and at other faculties at UiB (and beyond) that offer SDG-related courses at the graduate level.

This implies that we;

- encourage students to take SDG-relevant graduate courses for which they are eligible but that are not offered by the GSD;
- invite faculty from outside of the GSD to participate in a joint supervision of master thesis work during the 4th semester of the master´s education;
- establish a mechanism for credit sharing;
- develop individual study trajectories for the students who choose this option to qualify for the master´s level courses offered.

The structure of the Master´s Degree education in System Dynamics for students who opt for such an SDG specialization will then be:

Semester 1

Three foundation courses in modeling and analysis (GEO-SD 302, 303, and 304).

Semester 2

Three existing courses in the application of SD to the SDGs (GEO-SD 321, 325, and 330).

Semester 3

3 SDG-specific courses (SDG *, SDG **, SDG ***) at UiB (or abroad).

Semester 4

Jointly supervised Master´s Thesis.

The courses GEO-SD 308, 309, and 310 may be waived by the students opting for the specialization in the SDGs, and the spring semester version of GEO-SD 330 is then taken rather than the fall semester option.

Option I is no radical departure from the current master program; students have been encouraged to take courses from other departments so as to best prepare for their thesis research. However, hardly any students have opted for that version of the SD program. *This is grounded in the prequalification requirements posed by the various departments at UiB*. Most of our students are foreigners that do not hold a bachelor education from the UiB. Therefore, they are commonly considered ineligible for courses at the graduate level in most departments. Only a few Norwegian students have found an opportunity to combine a Master´s Degree education in System Dynamics with courses for which they are eligible (by way of their undergraduate education). The fact remains that Norwegian students have not been actively advised to seek a graduation education in System Dynamic nor on how to combine such an education with discipline-specific graduate courses for which they are eligible. Moreover, none of our three previous initiatives to collaborate across departments at the graduate level have been followed up. We would welcome a discussion on how that might change.

Since System Dynamics by design is a problem oriented, interdisciplinary method, the members of GSD share the attitude and the motivation to actively promote interdisciplinary education and research. Hence, the GSD is could end up more successful than others that have attempted to organize sustainable, interdisciplinary programs at UiB, though with little success, - possibly for formal reasons outlined above.

In light of the obstacles that students, interested in System Dynamics and sustainable development, face at the graduate level, we propose an Option II:

4.2.3 Option II: A more feasible and complete Program in Sustainable Development

Option II is an alternative Program in Sustainable Development that combines a Master´s with a Bachelor´s Degree. This more comprehensive program responds to UiB's ambitions and responsibility to offer a leading role nationally and internationally in bringing the SDGs into higher education through its role in Agenda 2030.

This option entails a university-wide bachelor education in sustainable development. It seems natural that such a program should be coordinated by the Faculty of Social Sciences since the social sciences represents the common element in all sustainability problems. While there may be little direct interaction between e.g. fisheries and energy production, both are important for social welfare. System dynamics is the interdisciplinary method serving as an integrator between sectors and disciplines, see Section 2[8]. At the bachelor level, the course prerequisites are less constraining. Thus students may select courses from a variety of departments. They will be guided to combine social sciences with one or a few domains with sustainability problems. Through the bachelor program the students will quality for the courses they need at the Master's level. Thus, the Master's program in sustainable development will be facilitated and strengthened.

Option II will require extensive collaboration across departments and faculties and at UiB, - a task that the GSD is prepared to take on in collaboration with the Faculty of Social Sciences. This option will meet three strategic priorities announced by UiB and the Faculty of Social Sciences;

- contributing to a more extensive, interdisciplinary integration of education and research on SDGs; and

[8] It should be noted that the UiB rectorate has recognized the need for system dynamics as one means to reach prioritized goals in the UiB strategy documents. It is seen as a most appropriate method to facilitate integrated problem-oriented teaching and research that reach across disciplines, and particularly important for the analysis of complex issues related to SDGs. Hence, SD is seen as an important ingredient in a UiB Master´s Degree Program on a green transition, for which the rectorate has sought funding from the Ministry of Education.

- becoming more attractive to resourceful students who are motivated by the current social movement for global sustainability.

Option II implies that we offer a large portion of the current system dynamics program in a version adapted for undergraduate studies. What remains to be taught of system dynamics at the graduate level, where the students specialize their studies are:

- one upgrade course (GEO-SD 305) for the downgraded courses GEO-SD 202, 203, and 204, such that they combined correspond to the courses currently taught at the graduate level;
- two advanced modelling, analysis and dissemination courses; and
- existing specialized, optional courses in the application of system dynamics to the domain of SDGs.

This would provide considerably room for an emphasis on sustainable development at the graduate level.

4.2.3.1 Bachelor´s Degree Program in Sustainability Development.

In what follows, we illustrate Option II in more detail i.e. how both the Bachelor´s and the Master´s degree level programme may be composed. It seems important to design a very flexible bachelor program where students are guided into combining courses that lead towards a thorough understanding of the SDGs problems that the students find most interesting. This can only be done in close collaboration with departments offering courses relevant to sustainable development. This proposal is, consequently, a demonstration of the feasibility of such a program.

Semester 1

- Ex.phil [10]
- GEO 110 [10] SV: Cartography and thematic maps
- GEO-SD 202 [10] SV: Fundamentals of Dynamic Social Systems

Semester 2

- GEO-SD 230 [10] SV: Natural Resources Management
- SDG 110 [10] SV: Perspectives on Sustainable Development
- SAMPOL 115 [10] SV: Democracy and Democratization

Semester 3

- GEO-SD 203 [10] SV: Model-based Analysis and Policy Design
- GEO-SD 204 [10] SV: System Dynamics Modeling Process
- GEO-SD 209 [10] SV: Model Based Interactive Learning Environments

Semester 4 & 5

Students are required to take 60 ECTS credits of elective courses at UiB or at European partner universities, - courses that are relevant to the SDGs. This may include courses in social sciences, business administration, innovation; natural sciences, engineering, medicine, psychology, law, and the humanities. The students should focus on a field of specialization of their choice. The study plan must prepare them for graduate courses of their choice. Here is a non-exhaustive list of SDG-relevant undergraduate courses that are currently taught at UiB:

- CET 201 [10] SV: Sustainable Innovation
- GEO 222 [10] SV: Sustainability in an Urbanising World
- SDG 213 [10] MN: Causes of Climate Change
- GEO 215 [10]SV: Geographical Information Systems: Theory and Practice
- SDG 213 [10]MN: Causes and consequences of Climate Change (SDG 213)
- SDG 214 UN [10] MN: Sustainable Development Goal 14: Life below water
- SDG 215 UN [10] MN: Sustainable Development Goal 15: Life on land

Semester 6

ECON225 [10]^{SV}: Political Economy (may require ECON110 as preparation)

GEO-SD 208 [10]^{SV}: Policy Design and Implementation

*SDG *** [10]: Bachelor thesis in Sustainable Development*

4.2.3.2 Master´s Degree Program in Sustainable Development

A bachelor program preparation makes it possible to offer a Master´s Degree Program in Sustainable Development with a much larger component of SDG-courses. If the number of System Dynamics courses is restricted to 4, there is room for 5 SDG courses (each10 ECTS). To support their thesis work, students can choose between existing domain-specific courses that they are qualified to take. They may apply to substitute other program courses with more domain specific courses. The domain-specific courses listed below, must, consequently, be considered proposals included to illustrate the feasibility of such a program. As the program is gaining recognition, there is reason to believe that faculties and departments will offer graduate courses, relevant to the SDGs, that may be included in the program.

Note that students may still choose to take the Bergen Master´s Degree in System Dynamics currently on offer. These students take a more advanced, original version, GEO-SD 302, -3, -4, - 8, and -9 of the three corresponding courses offered at the bachelor level as GEO-SD 202, -3, -4, -8, and -9. Students who have taken these three courses, GEO-SD 202, - 3, and -4 at the bachelor level, add a supplementary course GEO-SD 305, Advanced Case Studies in System Dynamics, at the graduate level.

Semester 1

GEO-SD 305 [10]^{SV}: Advanced Case Studies in System Dynamics

This course is an extension of the courses GEO-SD 202 and GEO-SD 203, is an integral component in GEO-SD 302 and GEO-SD 303, and is offered to students with a Bachelor´s degree in Sustainable Development. The course calls for the students to be immersed in graduate level case studies, specifically focusing on model analysis and policy design.

GEO-SD 316 [10]^{SV}: Advanced methods for modelling, model analysis, and optimization

This course addresses advanced methods, technique and tools have recently been developed so as to enhance the field of system dynamics and its application to complex domains. They include advances in formal methods such as statistics, artificial intelligence and machine learning that enhance our ability to;

- identify parameter values, relationships and structure;
- assess how well non-linear models replicate historical data;
- characterize the sensitivity of simulation results to uncertainty;
- characterize the relationship between model structure and model dynamics; and
- optimize the performance of policies.

so as to provide more reliable and useful insights and policy recommendations.[9]

GEO-SD 317 [10]^{SV}: An integrated approach to Sustainable development goals

This course addresses the synergies and trade-offs resulting from the fact that a policy, designed to reach the Sustainable development goals of Agenda 2030, typically affects more than one goal, and that a goal often is affected by many policies. Hence, there is call for a comprehensive, and integrated approach to policy design, - i.e. for model-based strategy development.

Semester 2

ECON 316 [10]^{SV}: Natural Resource and Environmental Economics

The environmental economic part of the course includes knowledge of concepts such as externalities, public goods and efficiency. In the course we will discuss policy instruments such as Pigouvian tax, subsidy for abatement, standards and tradable permits. The natural resource economic part of the course includes economic theory for renewable and non-renewable resources. Policy issues relevant for the oil and gas sector and fisheries are being addressed.

[9] Sterman, J. D. (2018). System dynamics at sixty: the path forward. *System Dynamics Review, 34*(1-2), 5-47. Sterman, J. D. (2019). Reply to commentaries on "System Dynamics at sixty: The path forward". *System Dynamics Review*, 35(1), 35-51.

GEO-SD 321[10]^{SV}: Model-based Socioeconomic Planning

This course, delivered in collaboration with the Millenium Institute (MI), focus on the use of the Threshold 21 (T21) model framework in comprehensive, integrated socio-economic planning. The course draws upon the experience MI has gained by applying the T21 in moe than 50 projects in development countries across 37 sectors. (Each year this course a number of planners from developing countries also graduate in this course. They offer our regular students a practical planning perspective to problems addressed in their home countries.

GEO-SD 325 [10]^{SV}: Client-Based Modeling Projects

Students analyse selected problems, typically associated with the Sustainable development goals, in direct collaboration with members of organizations and stakeholders that experience such problems. They learn the methods of 'group model building' and 'community-based modelling'. These methods help the analyst elicit information and feedback from those that have first-hand knowledge of the problems. The course also offers the students a realistic experience in working with clients and with presenting insights from SD-models to such clients.

Semester 3

GEO-SD 326 [10]^{SV}: Climate change and policies for energy transformation

The course addresses three important and interrelated EU 2030 targets regarding energy efficiency, renewable energy, and climate. The course describes innovative energy solutions. Interactive learning environments (ILEs) make use of DNV-GL's world energy model, and Climate Interactive's EN-ROADS model, and is being developed in collaboration with CET.

GLODE 301 [20]^{Psyk}: Critical Approaches to Development

The main aim of this course is to develop advanced comprehension of multi-level and complex processes of development and the role of institutional actors in these processes. The course will familiarize the student with the historical evolution of theories of development and encourage critical reflection on contemporary debates. The course will enable the student to identify and discuss different challenges to development posed by globalization, migration and climate change.

SDG 303[10]^{MED}: Global Health – challenges and responses

The objective of this course is to equip the students with concepts and perspectives for the analysis of global health challenges and responses in the context of the Sustainable Development Goals. This course aims for an understanding of the determinants of health, and health systems anchored in specific political, socio-economic, cultural and epidemiological settings.

Semester 4

Master thesis

4.2.4 Option III: An Honors and a Master´s Program in Sustainable Development

This third option is an Honors-version of the program described in section 4.2.3. An Honors program is an accelerated Bachelor program, typically encompassing what otherwise would be master´s degree courses. As the original course portfolio in System Dynamics is at the master´s level, the transition to an Honors program at the bachelor level is trivial: The structure of the program will be as outlined in section 4.2.4, yet the courses in system dynamics will be the original master´s versions: GEO-SD 302, 303, 304, 308, 309, and 330, - amounting to 60 ECTS. This leaves room for Ex. Phil, a Bachelor Thesis, and a number of specialized courses in SDG, amounting to a total of 120 ECTS in the Honors program.

Such a program will need to be developed in close collaboration with departments and faculties that take an interesting in jointly offering such a program. The challenge would be to develop a curriculum of advanced SDG-specific courses, amounting to 100 ECTS, constrained by merely a with minimum prerequisites.

4.3 Digital outreach, international partners, and funding opportunities

Focusing on the SDGs, UiB aims at empowerment by reaching an audience far apart in space in time. Moreover, when communicating insights into complex, dynamic domains, UiB must make use of innovative means of communication. Digital outreach is a means to address both of these concerns.

The GSD has been pioneering the development, assessment, and application of model-based interactive learning environments (ILEs). Such ILEs enable us to offer an education that;

- reaches out in space and time;
- flips the classroom from teaching to learning;
- facilitates learning by way of experimentation; and
- enhances our understanding of the relationship between structure and dynamics in complex domains.

Consequently, the GSD, not only offers education and conducts research into the development, assessment, and utilization of interactive learning environments. There is an ongoing development of ILEs, embedded both in the classroom and homework activities as well as in MOOCs delivered over the Internet.

The competence held by the System Dynamics Group in this field, has inspired our partners both in the EMSD program and beyond to collaborate with us in the development of project proposals addressing the EU and other funding agencies. These proposals range from the Erasmus Mundus proposal in which there is a strong emphasis on the utilization of ILEs in graduate education; the Erasmus+ proposal, entirely focusing on MOOC-based distance

learning at the undergraduate level; the Marie Curie proposal with a very strong focus on ILE-based knowledge dissemination within the SDG domain; and the Belmont Forum COAST Card proposal focusing on ILE-based, transformation of polluted bay-areas across USA and East Asia.

Not only does the System Dynamics Group cooperate with educational partners. Arguably more importantly, we work with institutions, such as UN, that are in need of reaching out to the communities most urgently in need of change in order to attain the SDGs. E.g. in Africa, working with UNEP on the EU-sponsored African Coexistence Landscapes project, we have been challenged to develop ILEs for the entire Kawanga-Zambezi Transfrontier Conservation Area (KAZA TfCA) in collaboration with the international KAZA secretariat and the local communities in that area. The urgency of this work is highlighted by the latest conference by the Convention on International Trade in Endangered Species (CITES). Our plan is, by way of the Erasmus+ program, to build capacity by;

- posting ILEs on the KAZA secretariat's web-site;
- reaching out to universities in Botswana, Zambia, Zimbabwe, Namibia, and Angola with an invitation to exchange students and faculty and to develop jointly web-based educational programs; and
- take similar initiatives, in concert with UNEP, in the African TRIDOM TfCA, in Brazil, in the Nepal/Butan/India triangle, in the Central-Asia republics, on Balkan and in Spain.

A similar initiative has been taken by our partner, the Millennium Institute. Recently MI converted its model framework, Threshold 21, to the technological platform Stella Architect employed by the GSD. Threshold 21focuses entirely on integrated SDG attainment and has been applied in more than 50 national development projects across the world. In collaboration with the GSD, MI reaches out to recruit students from developing countries by way of our MOOC GEO-SD 230 “Introduction to Integrated Development Planning with the Threshold 21 Model Framework” and collaborates with us in delivering the course GEO-SD 321 “Model-based Socioeconomic Planning”. GEO-SD 321 is the target of an effort to develop yet another MOOC of relevance to the SDGs.

We are in the process of converting the course GEO-SD302 to a MOOC, and our PhD candidate Aklilu Tadesse has developed and tested a MOOC that could complement parts of the GEO-SD303 course. Tadesse found considerable learning improvements and received a prize for his work at the 2019 SD conference. If successful, then the Erasmus+ application we resubmit next year, will enable GSD and its European partners to develop a series of SDG-related MOOCs at the bachelor level. This would further strengthen a bachelor program in sustainable development. Courses offered by our partners will then become easily available for our students with no need to travel and stay away for an entire semester. Individual courses could be blended with the ongoing bachelor program. UiB would only need to proctor the exams that will be prepared and graded by our partners.

With strong partnerships, the GSD expects that funding from local sources, NFR, DIKU, the EU, and international organizations will be within reach so as to co-finance our investments in the development and application of advanced educational technologies.

The development and application of MOOC technology is facilitated by our close research collaboration with isee Systems (USA) producing the Stella Architect software. Isee Systems´ developer is a graduate of the GSD and is currently a candidate in the PhD program of the Group. Moreover, Isee Systems´ ILE technology is fully in compliance with Canvas, the outreach technology employed by the UiB.

Over the first half of the10 year planning period, the GSD will develop its strength in digital education in prioritized areas, and will, consequently prepare a proposal to coordinate a national Center of Excellence in Education in collaboration with partners in Norway.

5 COLLABORATION WITHIN THE FACULTY AND THE UNIVERSITY

Due to its inherent interdisciplinary nature, system dynamics lends itself well and is at the same time dependent on collaborations across disciplines, policy sectors and stakeholder groups. We consider ourselves knowledge brokers and integrators for problem-driven interdisciplinary collaboration at the University of Bergen. Here, we focus on currently ongoing collaborations within the Faculty of Social Sciences and the University of Bergen. Also in the future, we see collaborations to be based mainly on specific research projects, educational activities and other initiatives.

5.1 Within department of geography

5.1.1 Teaching

Courses which we co-teach with geography staff:

- SD310, Writing course and project description, with assoc. prof. Peter Andersen (joint course responsibility). Joint course for geography master students (GEO310) and system dynamics master students (GEO-SD310).
- SD326, Special topic: Geographical perspectives on food, with prof. Ole Reidar Vetås (course responsible) and various faculty members of the department of geography.

Supervision:

- Co-supervision of master thesis Synnøve Beitnes (master in geography). Tentative title: "Klimatilpasning i norsk landbruket for økt robusthet under endrede forhold."

5.1.2 Research

Ongoing collaborative research projects:

- With assoc. prof. Kerstin Pothoff, SURE Farm Norway. Funding source: Research Council Norway (reinforcement grant to EU Horizon 2020 project SURE Farm – Towards SUstainable and REsilient EU FARMing systems). The primary objective of the SURE Farm Norway project is to assess how the environmental, economic and social developments described in the scenarios of the EU Horizon 2020 SURE-Farm project might affect the sustainability and resilience of low-intensity farming systems in Norway.

5.2 Within faculty of social sciences

5.2.1 Information and media sciences

One research proposals with assoc. prof. Morten Fjeld:

- Horizontal Collaborative Computing for Societal Negotiation Processes (NFR, IKT-PLUSS)

5.2.2 Center for Climate and Energy Transformation CET

- CET affiliate, contribution to project proposals
- New Water Ways project: The primary objective of New Water Ways is to spur the transition from traditional urban water management (UWM) to sustainable water-sensitive and climate-adapted UWM by assessing the social, economic and environmental implications of different infrastructure solutions, combinations of those and management strategies at multiple spatial scales. The work package led by the System Dynamics Group develops an integrated simulation model to assess the social, environmental and economic consequences of a future water-sensitive and climate-adapted UWM in comparison to traditional water management (baseline).
- Main supervisor of CET fellow Brooke Wilkerson. Tentative PhD thesis title: "Dynamic modeling of urban social-ecological systems: green-blue infrastructure for climate change adaptation."

5.3 Across faculties

5.3.1 PhD course “PhD for innovation. Interdisciplinary problem solving and creativity”

PhD for Innovation is a new, interdisciplinary course for PhD candidates at the University of Bergen. The course is led by a dynamic team that works across faculties. It demonstrates how researchers can engage in meaningful collaboration with non-university stakeholders to create new processes and products. The course therefore contributes directly to the call for innovation and entrepreneurship in the University of Bergen’s revised strategy for 2019–2022 ”Ocean, Life, Society”.

The purpose of this course is to equip Ph.D. candidates with problem-solving methods that facilitate interdisciplinary collaboration with a strong focus on research impact. This is achieved by working concretely with challenge-driven innovation related to sustainable development goals (SDGs), in teams consisting of PhD candidates with varied disciplinary backgrounds. By merging methods from fields such as system dynamics and innovation

methods and by working directly with societal actors outside the university, the course represents a novel and effective approach to fostering creative problem-solving abilities that goes beyond already existing courses.

In the spring semester 2019, we conducted a very successful pilot of the course. We are currently working on a strategy for scaling and further development of the course.

5.4 Other cross-faculty collaborations

- We have a joint PhD project with the Department of Geology with a focus on investigating mining of resources at ocean floors to establish background information for legislation before exploitation starts.
- We have had several joint projects with HelseVest and with Haukeland Hospital on projects ranging from Alzheimer's disease to hospital management.
- We have participated in the UiB cross disciplinary forum called "digital breakfast", where systems perspectives are central.

6 RESOURCE REQUIREMENTS

The current research and education of the GSD comply with the strategy of the University of Bergen as well as that of the Faculty of Social Science. The productivity of the GSD is significantly larger than the Faculty average. The staffing of the GSD does not correspond to the work-load of the group (Attachment 3).

For the Faculty of Social Sciences to offer the System Dynamics Group normal working conditions, there must exist a reasonable balance between work load, created by demand for research and education, and capacity. Moreover, the resource allocation must be predictable so as to recruit excellent faculty.

It has been argued by the GSD in our reports to the faculty and the rectorate that;

- the current workload corresponds to that of 4 faculty members;
- a reduction in the intake of students will not cause a significant reduction in the work-load (due to 3 semesters of the master´s program constituting 90 ECTS coursework that will be taught regardless of the number of students); and
- a reduction of the number of students will render the System Dynamics Group apparently over-staffed (due to the academic staff requirement model).

In section 4, we listed a number of alternative educational programs that the system dynamics group consider realistic. The current master´s degree program and the SDG-specific version of that program (Option I) may both (and in parallel) be offered by 4 faculty members.

As for Option II, a combined bachelor´s and master´s degree program, the system dynamics group will offer bachelor´s versions of current master´s degree courses; GEO-SD 302, 303, 308, 309 and 330. With the supplementary course GEO-SD 305, we, in essence, offer courses corresponding to GEO-SD 302 and GEO-SD 303 and GEO-SD 309. Moreover, elements of GEO-SD 316 cover advance topics in the course GEO-SD 330. The courses GEO-SD 304, GEO-SD 310, GEO-SD 321, and GEO-SD 325 remains unmodified in the master´s program. Consequently, there are two courses taught that requires resource beyond our current portfolio, - GEO-SD 316 and GEO-SD 317 (to be taught in collaboration with CET).

As for Option III, an Honors program combined with a master´s degree program, the resource requirements will be as for Option II. But the level of investment will be less as the courses in the portfolio will not have to be offered in modified version. Moreover, there will be no need for GEO-SD 305.

To conclude, the course portfolio under Option II and III may be offered by an academic staff of 4 professors, provided we can continue our collaboration with MI (GEO-SD 321) and isee Systems (GEO-SD 209). By making extensive use of flipped classroom teaching methods, interactive learning environments and MOOCs, our teaching is already, and can be made

even more efficient. What would be a challenge is, then as now, to find room for the development of ILEs and MOOCs and to account for sabbaticals and unforeseen leaves of absence. Needless to say, the number of students enrolling at the bachelor´s and master´s level under Option II, will also define the resource requirements. Should Option II be attractive to the Faculty and to UiB, we expect that resource will be allocated in accordance with *the general Faculty practice* and in accordance with the credits produced by the program.

ATTACHMENTS

Attachment 1: Common problem characteristics addressed by way of System Dynamics

1. The problems are associated with systems that develop over time, governed by an underlying systems structure.
2. The problems are comprehensive in the sense that they cut across sectors, private as well as public, and are multi-disciplinary in nature. They are not the responsibility of a particular organizational entity, nor do they "belong" to a specific scientific domain. Moreover, they typically involve a variety of stakeholders. There are several implications, among them;
   - Such problems are often not recognized comprehensively, rather as a set of individual problem components, manifesting themselves in various ways at different locations across time, resulting in low transparency, poor public recognition, late detection, erroneous attribution, weak democratic control, and, eventually, a call for radical intervention;
   - To the extent that such problems are being recognized, it is not well-defined who owns them and who has the responsibility for addressing them. The result is that no-one is compelled to address the problem, and everyone expects someone else to take the initiative to solve the problem;
   - When actually addressing the problems, it is difficult to determine whether the stakeholders share a common perspective and a common set of preferences, goals and visions. That makes it challenging to reach consensus as to the nature of the problems and to their solutions;
   - In cases where consensus could be reached, scientific disciplines and terminologies that span the entire problem domains are commonly not employed. Thus, it becomes challenging even to communicate effectively about such problems. Moreover, there is very limited access to competencies in methods, techniques, and tools developed to effectively identify and solve such problems. And, finally, for the same reasons, knowledge transfer is inhibited.
3. The problems arise from complex systems, characterized by an underlying causal structure of accumulation processes, the core of any dynamic system, that are interrelated by way of non-linear feedback structures that cut across sectors and disciplines. The resulting variety of lags / delays are spread across a system, makes the root cause of a problem nearly inaccessible, and masks the timing and dosage of effective interventions. In addition, circular causality, i.e. feedback, leads us into circular arguments, made meaningful only when we recognize the associated lags / delays. In non-linear systems, feedback loops synergize to impact the systems' dynamics. The influence of some

systems components is thus conditioned by the influence of others so that the effects are specific to the prevailing systems conditions (state) and experience is of limited value. It takes a structural (i.e. fundamental) understanding of such systems to effectively address associated problems. Because in non-linear systems the impact of each systems component changes over time, the governing substructure may be identified at any point in time so as to simplify policy analysis and facilitate an effective knowledge transfer that focuses on the essence of a problem. Successful interventions in such systems are typically aimed at reinforcing the significance of favourable components and attenuating the significance of less favourable ones. We may only accomplish that with the understanding that favourable structures often turn unfavourable as a consequence of the dynamics of the system itself, i.e. from within.

4. Our time horizon defines the problem as well as its solution and extensive time horizons imply more feedback and non-linearity: when our time horizon is relatively short, we may legitimately ignore relationships that play out over more extensive periods of time. Moreover, the state space in which the system operates (i.e. the operating space) is so limited that non-linear relationships do not play out. Thus, we may validly base our policy analysis on simple, open and linear models. In a longer time-perspective, that characterizes sustainable problem solving, we need to trace out, across sectorial and disciplinary boundaries, relationships that manifest themselves in feedback after only a major delay. Moreover, an extended time horizon widens the operating interval and activates dormant non-linear relationships in the systems structure. Thus, we are in need of a more comprehensive and endogenous problem perspective, more complex models, and a search for the cause of the problem within the system itself. In conclusion, incoherence, and thus inconsistencies, may arise between short-term and long-term planning, problem analysis and policy design. However, by widening the perspective in space (to include the feedbacks also in the shorter term) the time horizon widens as well and the same models may be applied across a wider time span. That way, short term decision making may become coherent and consistent with medium- and long-term policy analyses. This is of particular importance in our investigation of the interactions between the private and public sectors where the time perspectives typically differ significantly.
5. As a result of the complexity described above, problem and policy analyses are commonly compartmentalized as opposed to being comprehensive. One implication is that the impact caused by the dynamics of some sectors may differ from what policy developers in other sectors have come to expect. In the shorter run, this incoherence may not be of significance due to the time it takes for inter-sectorial effects to play out. In the long run, however, such incoherence typically leads to inconsistent policy conclusion resulting from the invalid set of assumptions upon which policies are being developed.
6. Effective problem solving implies that one does not “just” predict the future development of a system. One must identify the underlying causalities that will bring about that development and modify those causalities through effective policy design and implementation with the intent to change course. The “Impact Assessment Guidelines” of the Commission, updated in 2009, it is claimed that “You need to establish the ‘drivers’ – or causes – behind the problem (how particular factors lead to the problem) and the

ways in which these different drivers influence one another directly or indirectly". To that end, one needs a fundamental understanding, i.e. a causal theory, of the structural origin and nature of the problem as well as of the proposed policies to deal with the problem.

Attachment 2: PhD candidate tracer studies and status report 15.05.2019

20 Ph D kandidater utdannet 2002 - 2018

Navn (kjønn, disp. år)	Tema	Finansiering	Nasjon	Yrke
M. M. Saleh (M 2002)	Systemdynamisk analyse metode	Kvote-stipend	Egypt	**Professor** Kairo University, Egypt (https://scholar.cu.edu.eg/?q=saleh/)
A. Sawicka (F, 2004)	Informasjons-sikkerhet	Kristiansand kommune	Polen	Nasjonal Kommunikasjonsmyndighet (https://www.nkom.no)
M. Milrad (M, 2006)	Modell-basert media-teknologi	Svensk statsstipend	Brazil	**Professor** Linnaeus Universitetet , SE (https://lnu.se/en/staff/marcelo.milrad)
S. Arango (M, 2006)	Eksperimentell økonomi: Analyse av olje-markedet	Kvote-stipend	Colom-bia	**Professor** National University, Medellin **Senior Research Fellow** EfD Colombia (https://efdinitiative.org/about-efd/people/arango-aramburo-santiago)
D. Wheat (M, 2007)	Modell-basert økonomiutdanning	Wheat Resources	USA	**Professor:** a. UiB (emeritus), https://www.uib.no/en/persons/David.Wheat b. ISM, Lithauen https://www.ism.lt/node/3484 c. NaUKMA, Ukraina. http://finance.ukma.edu.ua/en/vikladachi/2011-05-07-23-00-03/vikladachi/vit-aira-devid
J. Wiik (M, 2007)	Nasjonal Informasjons-sikkerhet	Høgskole-finansiert, Agder	Norge	**Partner** Deloitte https://www2.deloitte.com
A. Qureshi (M, 2008)	National utviklings-planlegging med vekt på National Accounting Matrix	Kvote-stipend	Paki-stan	**Asc. Professor** Oslo MET https://www.oslomet.no/om/ansatt/muhaqu/
S. Kharib (M, 2008)	Landskapsplanl.. Gjennom koplede	Kvote-stipend	Egypt	**Senior Urban Designer** Dar Al Riyad Group, Saudi Arabia http://www.daralriyadh.com/en/

	GIS og SD modeller			
M. Pedercini (M,2009)	Modellbasert utviklings-planlegging	Millennium Institute	Italia	**Vice President & Chief Operating Officer** Millennium Institute: NGO innen offentlig bærekraftplanlegging: https://www.millennium-institute.org
A. Bassi (M. 2009)	Modellbasert analyse av energiomstilling på ulike aggregeringsnivåer	Millennium Institute	Italia	**CEO** KnowlEdge Srl : Rådgiver innen offentlig bærekraftsplanlegging: https://www.ke-srl.com
J. P. Ansah (M, 2009)	Gjeldsakkumulering og fattigdomsfellen i Afrika	Kvote-stipend.	Ghana	**Assistant Professor & Research Fellow** DUKE - National University of Singapore (NUS) Medial School, Health Services and Systems Research http://rc4.nus.edu.sg/fellows/john-pastor-ansah/
J. Radianti (F, 2010)	Det svarte market for datasikkerhet	Høgskole-stipend, Agder	Indo-nesia	**Forskningsleder** **CIEMlab** Senter for Integrert Krisehåndtering Universitetet i Agder https://home.uia.no/jaziarr/index/
Y. Qian (F, 2010)	Datasikkerhets-utfordringer ved automatisering av norsk sokkel	Høgskole-finansiert, Agder	Kina	**Asc. Professor** Shanghai University http://www.shu.edu.cn
M. Saldariaga (F, 2011)	Pedagogisk anvendelse av systemdynamikk I naturfag	Kvote-stipend	Colom-bia	**Ass Professor & Department Chair** Departm. of Mathematics and Nat Sci., American University of Irak https://auis.edu.krd/maria-saldarriaga-assistant-professor-mathematics-and-natural-sciences-department-chair
S. Derwich (M, 2012)	Patentrettigheter i matvareproduksjon; Forsterket mais i det sørlige Afrika	CGIAR	Tysk-land	**Forsker** Business Application Research Centre www.barc-research.com
J. Hartwig (M, 2017)	Målkonflikter mellom patentretten, vekst og konjunktur.	Frauenhofer Universitets-stipend	Tysk-land	**Senior Economist** MFive GmbH Mobility, Futures, Innovation, Economics https://www.m-five.de https://www.linkedin.com/in/johannes-hartwig-942078b1/?locale=zh_CN

A. Gerber (M, 2017)	Agriculture-based food security in South Sahara Africa: Central policies and local adaptation.	NFR stipend	Sveits	**Post Doctoral Fellow** Department of informatics Sustainability Research Group, University of Zürich https://www.ifi.uzh.ch/en/isr/people/people/gerber.html
D. Lara Arango (M, 2018)	Eksperimentell økonomi: El. kraftmarkedet og kraftoverføring	Kvote-stipend	Colom - bia	**Seniorkonsulent** Business Intelligence Webstep https://www.webstep.no/ansatt/david-lara-arango/
H. Herrera (M. 2018)	Bærekraft i sosio-økologiske systemer under klima-skifte	Palermo universitets-stipend	Guate-mala	**Specialist Consultant** a. Department for Business, Energy & Industrial Strategy https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy b. UNEP https://www.unenvironment.org
Y. J. Lee (F. 2018)	Mental sykdom fanger I California; - behandling og bærekraft.	Palermo Universitets-stipend	Malay-sia	**Post Doctoral Fellow** Universitetet i Agder

16 Ph D kandidater under utdanning

Navn (kjønn, est. disp. år)	**Nasjonalitet**	**Finansiering**	**Tema**
S. Hackett (M, 2019)	Norge	Universitets-stipend	Analyse av integrerte evalueringsmodeller (integrated assessment models (IAMs)) i lys av klima-endringer.
A.S. Abdel-Afou (M.2019)	Palestina	Høgskole-stipend, Ålesund	Agent-basert modellering for forvaltning av oppdrett i åpne marine miljø
S.M.Blanco (M, 2019)	Spania	Universitets-stipend	Malaria, - en modell-basert analyse av den epidemiologiske utvikling i Kenya og Etiopia.
A. Tadesse (M, 2019)	Etiopia	Kvote-stipend	Teori, metoder, teknikker og verktøy for utvikling og evaluering av modell-baserte interaktive læremiljø

E. Romanenko (M,2019)	Russland	Palermo Universitets-stipend	Betingelser for bærekraftig kommersialisering av teknologier for karbon-fangst, lagring (CCS) og utnyttelse i olje-produksjon (EOR).
O. Chique (M, 2020)	Venezuela	Palermo Universitets-stipend	Finansielle og fysiske betingelser for et bærekraftig råoljemarked.
O. Tolmachova (F, 2020)	Ukraina	Palermo Universitets-stipend	Betingelser for et bærekraftig system for ivaretakelse av folkehelsen i Lombardia (Italia) med fokus på kroniske sykdommer.
A. Khan (F, 2020)	Pakistan	Pakistansk stipend	Analyse av betingelsene for private bedrifters finansielle bærekraft.
E. F.B. Alias (F, 2020)	Malaysia	Malaysisk stipend	Matvaresikkerhet i Malaysia: Co-farming av ris og fisk.
W. Schoenberg (M, 2020)	USA	Isee Systems	Teori, metoder, teknikker og verktøy for modellering, analyse og optimalisering av komplek-se dynamiske systemer og for formidling av systeminnsikt.
G. Pallaske (M, 2021)	Tyskland	KnowlEdge Srl.	Bærekraftig utnyttelse av landområder gjennom bedre planlegging basert på en syntese av systemdynamikk og geografiske informasjonssystemer.
D. Qorbani (M, 2021)	Iran	Sveitsisk Høgskole-stipend Bern	Model-basert verdikjede-analyse av Industry 4.0 prosjekter innen bærekraftige energi-transformasjonsprosesser.
A. Aguilar (F, 2021)	Colombia	CoCreate (Horizon 2020)	Co-Create (Horizon 2020): En modell-basert studie av overvekt og holdninger til overvekt blant ungdom, matvareprodusenter og myndigheter i Europa.
D. Kliem (M, 2021)	Sveits	Nat Research Progr. 73; Sustainable Economy	Model-basert analyse og ledelse av omstillingsprosesser i bygningsindustrien.
B. Wilkerson (F, 2021)	USA	Universitets-stipend	Modell-basert evaluering av grønn-blå infrastrukturtiltak i urbane miljø.
L-K. L. Trellevik (M, 2021)	Norge	Universitets-stipend	Dyphavsressurser – bærekraftig innovasjon, eksplorasjon, produksjon.

Attachment 3: The GSD production and productivity, - current practice

The System Dynamics Group currently (May 15., 2019) hosts 3 professors:

- Professor Pål I. Davidsen
- Professor Erling Moxnes
- Professor Birgit Kopainsky

16 Ph D candidates, of whom 13 are externally funded, - corresponding to a total annual value of about 13 mill NOK.

The table below exhibits the productivity of the GSD, relative to that of the Faculty of Social Sciences;

- the 3-year average production of credits and Ph D candidates upon which the staff requirement model is based;
- the short-term production of credits (2017) and Ph D candidates (2016 – 19) upon which the operating budget is based:
- the operating budget;
- the production of publication credits; and the
- the income from external sources (BOA-income)

for 2016 - 17.

The red numbers in the table below demonstrate that the System Dynamics Group is considerably more productive than indicated by the Faculty-average. This is reflected in the operating budget allocated, - 2.26 times the Faculty average. Applying the academic staff requirement model, a deficit of 1.3 staff members may be demonstrated. When not employed to the GSD, the Faculty may require the GSD staff to exhibit a productivity 2.5 times the Faculty average to legitimize a work relieve of 33% per employee by hiring one additional staff member. Such a discrimination is a breach of existing agreements and is inacceptable. It implies working conditions that will block the recruitment of academic staff members.

Long-term production of annual credits and Ph D candidates per employee (3-year average), -the basis for the academic staff requirement model:			
Program	**GSD**	**Faculty**	**Relativ Productivity SDG / Faculty**
Master	31	17.79	**1.78**
Ph D	0.23	0.18	**1.27**
Short-term production of annual credits and Ph D candidates per employee, -the basis for the operating budget:			
Program	**GSD**	**Faculty**	**Relative Productivity GSD / Faculty**
Master	34.5	18.4	**1.88**
Ph D (2017)	0.67	0.15	**4.46**
Ph D (2018)	1.00	0.15	**6.66**
Ph D (2019)	1.66	0.15	**11.1**
Operating Budget 2019 per Employee; - a reflection of current productivity:			
År	**GSD**	**SV-fak**	**Relative Productivity GSD / Faculty**
2019	370 000 NOK	160 000 NOK	**2.26**
Publication Credits per employee:			
År	**GSD**	**Faculty**	**Relative Publication Credits GSD / Faculty**
2017	4.00[1)]	2.77	**1.44**
External (BOA) income per employee (over and beyond 13 mill NOK i international stipend-financing of Ph D candidates):			
År	**GSD**	**SV-fak**	**Relativ BOA-inntjening GSD / Faculty**
2016	772 000 NOK	459 000 NOK	**1.68**
2017	943 500 NOK[1)]	536 000 NOK	**1.76**

1) In 2016/17 the GSD was staffed by merely 2 persons.

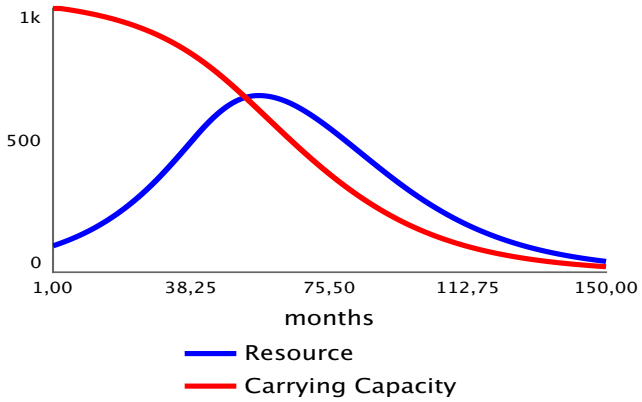
Attachment 4: Report to the rectorate

Gruppen for systemdynamikk (GSD)

Status 1. mai 2019

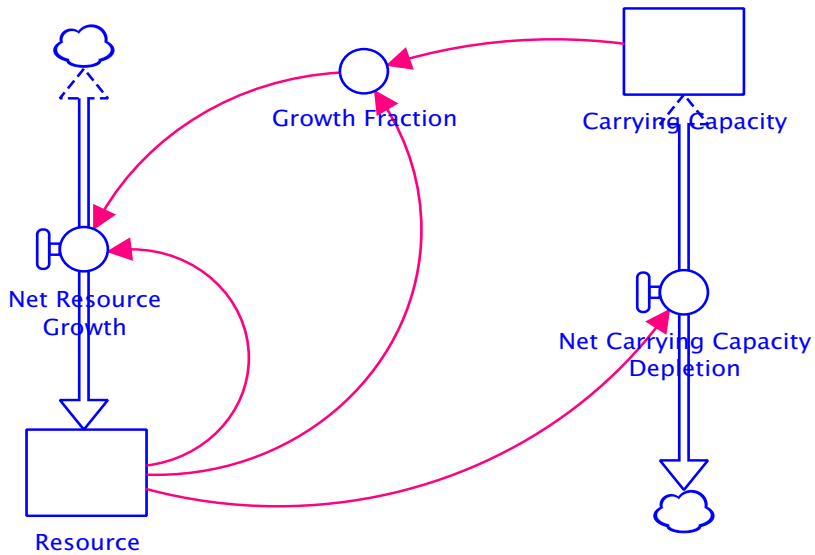
An integrated perspective on SDGs by way of modeling, analysis and dissemination;

the dynamics



of

accumulation, feedback and nonlinear interaction



Innhold

6.3. Konklusjon

1. Innledning

Gruppen for systemdynamikk (GSD) sprang ut av undervisning og forskning ved Institutt for informasjonsvitenskap. Som et uttrykk for fagets prominens ved UiB, ble grunnleggeren av fagområdet systemdynamikk, Prof Jay W. Forrester, MIT, oppnevnt til æresdoktor ved Universitetet i Bergen så tidlig som i 1990. I 1995 ble et internasjonalt master- og doktorgradsprogram innen fagområdet etablert etter initiativ fra Universitetsdirektøren.

Fom 2004 har gruppen vært organisert som en egen økonomisk enhet ved fakultetet og knyttet til Institutt for geografi. GSD omfatter p.t. 3 professorater og 16 doktorgradskandidater. Gruppen er det ledende forsknings- og utdanningsmiljøet i Europa på dette fagområdet og regnes p.t., sammen med MIT som ledende også på verdensbasis.

I perioden 2003 – 2020 vil 4 av gruppens tilsatte ha innehatt lederskapet i System Dynamics Society, - herunder den første kvinne. To av gruppens medlemmer er blitt tildelt hhv. forskningsprisen Jay W. Forrester Award og SDS Distinguished Service Award. En rekke studenter er, gjennom årene, blitt tildelt Donella Meadows Award for beste studentarbeid.

Arbeidsmarkedet for våre kandidater er svært gunstig. Globalt er det stor etterspørsel etter kandidater med kompetanse i integrert analyse av komplekse systemer og utvikling og evaluering av politikk på tvers av fagfelt og samfunnssektorer. Eksempelvis etterspør EU i flere av sine policy-dokument denne typen kompetanse (se avsnitt 2.). Videre påpeker Council for Science and Technology, UK Government Office of Science, i sin rapport "Computational Modeling: Technological Futures", 2018, ´på behovet for kompetanse i modellering og da med eksplisitt referanse til systemdynamikk.

Som uttrykk for hvor godt systemdynamikk egner seg som tverrfaglig metode, publiserer GSD i topp journaler innen management (*Management Science*), political science (*Journal of Conflict Resolution)*, økonomi (*Journal of Environmental Economics and Management*), medisin (*Drug and Alcohol Dependence)* og naturligvis innen systemdynamikk (*System Dynamics Review*).

Som det fremgår av en tracer-studie, innehar 65% av våre uteksaminerte PhD-kandidater ledende undervisnings- eller forskerstillinger ved høyere akademiske institusjoner, - ca. 40% av våre EMSD studenter er i akademiske rekrutteringsstillinger og en rekke av våre tidligere masterstudenter har disputert ved andre undervisningsinstitusjoner og er professorer ved universiteter verden over.

GSD har et aktivitetsnivå og en produktivitet som langt overstiger fakultetsgjennomsnittet. Bemanningen står ikke i forhold til gruppens arbeidsmengde. Arbeidsbelastningen er uholdbar. Dette skyldes at fakultetsledelsen ikke respekterer de bemanningsbetingelsene

som ble nedfelt i avtalen om fristilling av GSD fra Institutt for informasjonsvitenskap (se avsn. 6).

2. Fagområdet systemdynamikk og dets anvendelse innen SDG-studier

Systemdynamikk er studiet av komplekse, dynamiske systemer som spenner over et mangfold av fagområder og samfunnssektorer. Strukturen i slike systemer utgjøres gjerne av ulineært koplede feedback-løkker, preget av tidsforbruk (forsinkelser) og usikkerhet. Resultatet er en dynamisk utvikling over tid som det ofte er vanskelig å tolke og enda mer krevende å styre.

Faget er operasjonelt og i kjernen av faget utvikler vi teori, metoder, teknikker og verktøy for modell-basert;

- kunnskapsinnsamling med ekspert- og interessent-medvirkning;
- analyse av sammenhengen mellom komplekse systemers struktur og dynamikk;
- utforming prinsipper for beslutningstaking, forankret i en overordnet strategi; og
- utvikling av interaktive læremiljø, herunder globale flere-bruker spill og MOOCs, som bidrar til formidling av innsikt i komplekse, dynamiske systemer.

Ved UiB anvendes systemdynamikk i hovedsak for å studere hvordan bærekraft-målene nedfelt i Agenda 2030 kan bli oppfylt. Spesielt analyserer vi *samvirket* mellom den politikk som legges til grunn for måloppnåelse innen de enkelte samfunnsområder (f. eks. helse, utdanning, ressursforvaltning, klima, og økonomi), - hvilke motsetninger som kan oppstå og hvilke synergier som kan utnyttes.

Målet er å utvikle simuleringsmodeller som er så realistiske og gjennomsiktige at mennesker som skal bidra til å oppfylle bærekraft-målene, gjenkjenner virkeligheten i modellene. På den måten kan de ta eierskap i modellene. Og slik sikrer vi at de strategiske og taktiske konklusjonene som arbeidet leder fram til, får gjennomslag i praktisk politikk.

Modeller nytter vi også til å *formidle* innsikt i komplekse, dynamiske systemer. Vår forskning viser at lærende kommer til dype erkjennelser ved *bruk* av slike modeller. Vi utvikler derfor interaktive læremiljøer som inkorporerer simuleringsmodeller på en sømløs måte. Slike læremiljøer tar gjerne form av globale internett-spill for flere aktører og viser seg å ha en betydelig pedagogisk effekt. Læremiljøene gir de lærende et risiko-fritt laboratorium for utprøving av egne beslutninger i form av en scenario-analyse eller i samvirke med andre beslutningstakere. Studiet av lærende under arbeid i slike kontrollerte miljøer setter oss forskere i stand til å videreutvikle vår formidlingsevne og den læringsteknologien vi gjør bruk av.

Det å satse på bærekraft-målene innebærer bl. a. at vi må rekke ut til et globalt publikum; -til våre studenter og til andre som dra nytte av vårt forskningsarbeid. I så måte spiller

digitalisering og MOOCs en helt sentral rolle. Vår kompetanse i utvikling av modell-baserte interaktive læremiljøer, gir oss en internasjonal lederrolle på feltet.

Etterspørselen etter vår kompetanse knyttet til bærekraft-målene illustreres godt av de vi skriver i innledningen til vår 2019 Marie Curie søknad (SDG IMPACT):

"SDG IMPAKT – "**Sustainable Development Goals: Integrated Model-Based Policy Analysis and Knowledge Transfer" –** is intended to build capacity in the assessment of policies designed to attain the United Nations (UN) Sustainable Development Goals (SDGs) set out by Agenda 2030[10], and in effective transfer of the knowledge gained to SDG professionals, students of the SDGs, and the public at large. SDG IMPAKT will educate a cohort of 15 creative, entrepreneurial and innovate early-stage researchers (ESRs) in the:

- integrated model-based design and analysis of policies aimed at the attainment of the SDGs; and
- transfer of knowledge gained, by way of model-based innovative, interactive learning environments (ILEs), - made publicly available to strategy developers, policy designers, decision makers and, in the form of MOOCs, to SDG students and to the public at large so as to facilitate world-wide access to free education, transparency, and broad engagement in the sustainable development domain.

In Europe and elsewhere, addressing SDGs in an **integrated** way is a societal imperative of outmost importance. This has been recognized by the UN and articulated by stakeholders, scientists, politicians, administrators, and the public. The SDGs feature in all of the European Commission's 10 priorities[11]. In 2016, the European Commission outlined its strategic approach towards the implementation of the 2030 Agenda, including the Sustainable Development Goals, by declaring "sustainable development as an essential guiding principle for all European Commission policies" and by outlining the next steps for a sustainable European future [12].

The need for an integrated approach originates from the comprehensive and complex reality that the SDGs address. However, our **capacity to develop such an integrated perspective, including adequate theories, methods, techniques, and tools, remains unavailable to most professionals (strategy developers, policy designers, and decision makers), - and to the public at large.** As emphasized by Nilsson et al.[13], "Implicit in the SDG logic is that the goals depend on each other - but no one has specified exactly how. International negotiations gloss over tricky trade-offs". Moreover, the European Commission has, since the turn of the century, called for rigorous impact assessments of planned policies and actions with emphasis on long term sustainability[14] and stated, more recently, that "We should make policy choices that ensure that our various objectives are mutually reinforcing. Actions that promote competitiveness, growth, and jobs, as well as economic and social cohesion and a healthy environment reinforce each other. These are all essential components of the overarching objective of sustainable

10 UN General Assembly (2015). Transforming our world: the 2030 Agenda for Sustainable Development, 21 October 2015, A/RES/70/1. Available at: https://sustainabledevelopment.un.org/

11 https://ec.europa.eu/commission/priorities_en

12 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52016DC0739&from=EN

13 Nilsson, M., D. Griggs and M. Visbeck (2016). "Policy: map the interactions between Sustainable Development Goals." *Nature News* **534**(7607): 320.

14 https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and- how/better-regulation-guidelines-and-toolbox_

development, on which we must deliver"[15]. Finally, according to **the Operational Research Society**[16]**:** "In 2017, the UN, the World Health Organization (WHO), and the Organization for Economic Co-operation and Development (OECD) all publicly declared **systems thinking** to be a **key leadership skill** that is necessary to deal with the fundamental interconnectedness of complex, local-to-global economic, social and environmental issues". The **SDG IMPAKT will train candidates to identify precisely how the SDGs are interrelated, to communicate their findings through effective means of knowledge transfer, and to develop the systems-based leadership skills called for**.

SDG IMPAKT proposes a unique research programme on **model-based, integrated policy design, analysis, and knowledge transfer to enhance and promote a well-balanced attainment of the SDGs**. This programme is complemented by an **advanced professional training programme to strengthen ESRs´ transferable skills."**

3. Forskning og internasjonalt forskningssamarbeid

Gruppen for systemdynamikk deltar i et omfattende forskningssamarbeid med en rekke institusjoner og med noen private virksomheter som alle har en innretning mot bærekraft--målene. Noen av disse samarbeidsprosjektene, omtalt i dette avsnittet, er finansiert av EU, ett av NFR, og flere er privat-finansierte. I avsnitt 5 omtales en rekke initiativ vi nylig har tatt til internasjonale forsknings- og undervisningssamarbeid.

3.1. HORIZON 2020 prosjekter

3.1.1 CO-CREATE (https://www.fhi.no/en/studies/co-create/ *):*

Dette prosjektet er ledet av Folkehelseinstituttet i Oslo. 14 institusjoner fra en rekke Europeiske land, Australia og Sør-Afrika deltar. Studien «Confronting obesity: Co-creating policy with youth» omhandler en bærekraftig forebyggende helsepolitikk der vi undersøker hvordan samfunnet kan legge til rette for at ungdom velger et sunt kosthold og en aktiv livsstil. Et hovedformål er å begrense utbredelsen av «livsstilssykdommer». Systemdynamikk nyttes til å fange ungdoms egen opplevelse av livsstil, herunder forhold til kosthold og helse, i simuleringsmodeller, - modeller som så suppleres med kunnskap fra andre kilder; forskning, offentlig forvaltning, næringsliv og interesseorganisasjoner. Modellene vil bli lagt til grunn for utforming av effektive, forebyggende tiltak som bidrar til å ivareta folkehelsen. Ph D kandidat Anaely Agular, Colombia, er tilsatt i dette prosjektet.

3.1.2 SURE Farm (Horizon2020) (https://surefarmproject.eu/):

Dette prosjektet er ledet av Universitetet i Wageningen. 11 universiteter og 5 forskningsinstitusjoner fra en rekke Europeiske land deltar. Studien «Towards SUstainable and REsilient EU FARMing systems» omhandler bærekraftig matvareproduksjon i landbruket og undersøker betingelsene for en bærekraftig og motstandsdyktig produksjon av mat i EU

[15] The Commission's Strategic Objectives 2005-2009, COM(2005).
[16] **The Operational Research Society, The OR Blogs**, https://www.theorsociety.com/Blog/features/20180313124138.aspx

under den usikkerhet som preger klima og samfunnsforhold (befolkningsutvikling, urbanisering etc.). Prosjektet er innrettet mot verdikjeder i matvareproduksjonen og er knyttet til programområdet: «Sustainable Food Security – resilient and resource efficient value chains». Systemdynamikk nyttes til å utvikle modeller av verdikjeder, og i utforming og gjennomføring av scenario-analyser og konsekvensvurderinger.

3.2. EU-strategiske Programmer:

3.2.1 UNEP: Africa's Coexistence Landscapes: Securing their Future for People, Elephants and other Wildlife.

Finansiering: DG ENV / DG DEVCO ENRTP-GPGC Strategic Programme.

Som ledd i vår satsing på bærekraft-målene inngikk UiB nylig en MoU med UNEP. Studien «*Africa's Coexistence Landscapes: Securing their Future for People, Elephants and other Wildlife»* (se vedlegg 3a) omhandler bærekraftig utnyttelse av afrikanske landskap som deles mellom dyr og mennesker. En bærekraftig sameksistens mellom dyr og mennesker er en betingelse for å opprettholde slike landskap, - i dette tilfellet to av de største, internasjonale landskapsvernområder i verden; Transfrontier Conservation Areas (TfCA) KAZA (Kavanga / Zambezi), delt mellom Botswana, Angola, Namibia, Zambia og Zimbabwe (se vedlegg 3b) og TfCA TRIDOM (se nedenfor).

Det er enighet i alle ledd av prosjektet;

- i FN/UNEP;
- i KAZA TfCA sekreteriatet; og
- blant de fem ministrene som utgjør den internasjonale styringsgruppen for KAZA,

om at systemdynamikk (modellering, simulering, analyse og formidling) er den integrerende metoden som skal anvendes i dette prosjektet. Vårt arbeid med UNEP vil siden omfatte et tilsvarende TfCA, TRIDOM (Tri national Dja-Odzala-Minkebe), som omfatter deler av Cameroon, Gabon og Congo, og andre vernede områder verden over, - bl. a. India/Nepal/ Buthan, sentralasiatiske nasjoner, Brazil, Balkan og Spania.

3.3. Konsortium-finansierte prosjekter

3.3.1 The LIVES Project (https://livesproject21.org/):

Dette prosjektet, finansiert av NOMIS og MAVA, ledes av Universitetet i Geneve. Prosjektet «The Lives Project» tar for seg bærekraftig utnyttelse av naturressurser (ecosystems services) i krysningspunktet mellom mat, vann og energi og fokuserer på Cambodia og Colombia. Studiet av potensielle konflikter og mulige synergier mellom oppfyllelsen av bærekraft-mål står sentralt i prosjektet. Til dette formålet nyttes modellbasert kunnskapsinnsamling, analyse og formidling. I prosjektet deltar p.t. 6 universiteter og forskningsinstitusjoner, 3

interesseorganisasjoner og 1 konsulentselskap som er spesialisert i systemdynamisk modellering og analyse.

3.3.2 CIGIAR (Consultative Group for International Agricultural Research) CCAFS (Climate Change, Agriculture and Food Security) prosjekt

GSD samarbeider, innen rammen av CCAFS, med prof. Chuck Nicholson, Dyson Cornell, SC Johnson College of Business, USA,i et prosjekt som omhandler gapet som foreligger i lav- og middel-inntektsland mellom anvendelsen av systemanalyse i landbruksforskning og den foreliggende bærekraft i matvaresikkerhet. Formålet er å sette en agenda for å lukke dette gapet vha. systemdynamisk modellering og analyse.

3.4. NFR-finansierte prosjekter

3.4.1 KLIMAFORSK: New Waterways - towards water-sensitive and climate-adapted Nordic cities

GSD deltar i et nasjonalt samarbeidsprosjekt, ledet av Norsk Institutt for Vannforskning, finansiert av NFR med fokus på bærekraftig vannforvaltning i urbane sentre. Prosjektet omhandler nye løsninger som tar oss videre fra dagens konvensjonelle urbane vann-forvaltning (UVF), herunder overvannshåndtering. Ved å nytte modellering, er siktemålet å analysere hindringer og potensielle mekanismer for intervensjon. Dette ventes å gi ny kunnskap og bane veien for hvordan den nåværende norske vannforvaltningen i byer kan omdannes til et vannsensitivt og klimatilpasset samfunn. Resultatet skal hjelpe norske byer til å bli forbilder i overgangen til bærekraftig UVF - fra drenerte byer til grønne, levende, klimatilpassede og vannbevisste byer.

3.5. UiB- og høgskolefinansierte prosjekter

3.5.1 Agent-basert modellering for forvaltning av oppdrett i åpne marine miljø

I et samarbeid med Høgskolen i Ålesund, nå NTNU, ble GSD tildelt en stipendiatstilling innen den marine sektor. Prosjektet har ledet fram til en doktoravhandling basert på et modell-basert studium av betingelsene for et bærekraftig havbruk i et norsk fjordmiljø av patogener. PhD kandidat Alalyat Saleh Abdel-Afou, Palestina, har vært tilsatt i dette prosjektet og har nylig avsluttet sitt avhandlingsarbeid.

3.5.2 Analyse av integrerte evalueringsmodeller (integrated assessment models (IAMs)) i lys av klima-endringer

Som ledd i satsingen på klima-forskning ved UiB, ble GSD tildelt en stipendiatstilling for å vurdere betydningen av feedback knyttet til naturlig kapital i klassiske «Integrated Assess-ment Models». I prosjektet «Feedback effects of natural capital in the integrated assessment of global warming» blir det gjort en vurdering av fire forhold som ikke er

representert på en tjenlig måte i slike modeller; - naturlig kapital uten innvirkning på klimaet, økonomiske konsekvenser ved klimatisk ødeleggelse av naturlig kapital, endret teknologisk utvikling; og endogen strukturell endring i etterspørsel. Prosjektet har bidradd til å identifisere årsaker til den uenighet som foreligger omkring klimatiltak og gir forslag til forbedring av klassiske «Integrated Assessment Models». PhD kandidat Stian Hacket, Norge, har vært tilsatt i dette prosjektet og har nylig avsluttet sitt avhandlingsarbeid.

3.5.3 Teori, metoder, teknikker og verktøy for utvikling og evaluering av modell-baserte interaktive læremiljø

I et samarbeidsprosjekt med programvareleverandøren isee Systems, USA, (se 3.6.1) tar vi i bruk teori, metoder, teknikker og verktøy for utvikling og evaluering av en rekke web-baserte interaktive læremiljø. I dette prosjektet nyttes programvaren Stella Architect til en sømløs utforming av underliggende simuleringsmodeller og web-baserte læremiljø og til innsamling av brukerinformasjon som forteller om de lærendes bruk og nytte av læremiljøet. Slik informasjon danner grunnlag for læringsforskning: Den forteller oss hvilke problemer de lærende har i møtet med komplekse, dynamiske problem og hvordan slike miljøer kan utformes på en måte som fremmer god læring. En PhD kvote-stipendiat, Aklilu Tadesse, Etiopia, arbeider i dette prosjektet sammen med en rekke masterstudenter.

3.5.4 Malaria, - en modell-basert analyse av den epidemiologiske utvikling i Kenya og Etiopia

Som ledd i satsingen på klima-forskning ved UiB, ble GSD tildelt en stipendiatstilling å gjennomføre en modell-basert analyse av utbredelsen av malaria i Kenya og Etiopia på regionalt og nasjonalt nivå. Analysen er basert på en eksplisitt representasjon av livssyklusen til malaria-myggen og - parasitten. Studien gjennomføres i samarbeid med Millennium Institute (https://www.millennium-institute.org), Washington, DC.

Et av de viktigste funnene i denne studien er at forholdet mellom malaria-prevalensen i hhv. mygg og mennesker er lik en konstant som avhenger av entomologiske faktorer og det gjennomsnittlige antall bitt per mygg. Det er mange konklusjoner som følger av et slikt resultat, - herunder at en høy-prevalens blant mennesker er forenlig med en lav prevalens blant mygg. Under slike forhold er transmisjonsraten betinget i mindre grad av mygg-tettheten enn av malaria-prevalensen blant mennesker. Derfor bør smitte-reduserende tiltak innrettes mot en reduksjon av smitte fra mennesker til mygg. PhD kandidat Santiago MovillaBlanco, Spania, er tilsatt i dette prosjektet.

3.5.5 Modell-basert evaluering av grønn-blå infrastrukturtiltak i urbane miljø

GSD samarbeider med Center for Climate and Energy Transition (CET) ved UiB i et prosjekt der grønn-blå infrastrukturløsninger vurderes som ledd i det å redusere klima-utslipp i urbane miljø og det å gjøre urbane strøk mer motstands- og leve-dyktige i møte med klima-endringer. Til dette kreves en systemtilnærming som gir innsikt i urban kompleksitet; - sam-

spillet mellom mennesker, naturlig miljø og bygget miljø, og skaper et grunnlag for utvikling av en bærekraftig politikk for utvikling av urbane sentre. I prosjektet gjennomføres en modell-basert scenario-analyse der gjennomførbarheten og effekten av en rekke grønn-blå tiltak blir vurdert. I dette prosjektet finansierer CET en PhD kandidat, Brooke Wilkerson, USA.

3.5.6 Dyphavsressurser – bærekraftig innovasjon, eksplorasjon, produksjon

I et samarbeide med Havlaboratoriet, Mat Nat fakultetet, ble GSD tildelt en tverrfakultær stipendiatstilling innen den marine sektor med fokus på en bærekraftig utnyttelse av dyphavsressurser.

Formålet med dette prosjektet er å studere det dynamiske samspillet mellom innovasjon, eksplorasjon og produksjon med tanke på å utnytte ressurser på store havdyp.

For først å peke på det innovative aspektet ved denne forskningen, vil en bl.a. se på basalt-lagene langs Atlanterhavsryggen som et reservoar for kjemisk binding og lagring av CO_2. Dette vil kunne gjøre gass-produksjonen i Nordsjøen og de nordlige havområder bærekraftig også i et miljø-perspektiv. Lagringsplass for CO_2 er altså i seg selv en dyphavsressurs.

For dernest å illustrere dynamikken i utnyttelse av dyphavsressurser generelt, kan vi slå fast at investeringer må komme som et resultat av inntektene fra ressursproduksjon og vil være betinget av den foreliggende markedstilstanden, det etablerte skatteregime etc. Investeringer vil bli splittet mellom utnyttelse av foreliggende teknologi og utvikling av ny teknologi, - det være seg eksplorasjons- eller produksjonsteknologi.

Foreliggende produksjonsteknologi utnyttes i den grad ressursen er identifisert og er økonomisk drivverdig. Om den ikke lenger er det, står vi overfor to valg. Vi kan utvikle ny produksjonsteknologi gjennom innovasjon for å kunne utnytte mer effektivt eller i større omfang den ressursen som allerede er identifisert. Alternativt kan vi investere i ytterligere eksplorasjon gjennom utnyttelse av foreliggende teknologi med sikte på å gjøre nye funn. Eller vi kan gjøre begge deler. Om den foreliggende eksplorasjonsteknologien ikke lar oss finne mer, kan vi velge å videreutvikle også den gjennom investeringer i innovasjon.

Som vi opplever i dagens olje- og gass-industri, er fysiske ressurser ikke fornybare. Over tid oppstår det derfor et produktivitetstap, som vi vil søke å kompensere med ytterligere investeringer i innovativ teknologi-utvikling. Biologiske ressurser er gjerne fornybare, forutsatt at de forvaltes fornuftig og høstes på en bærekraftig måte. Dette innebærer at produksjonsteknologien er en forvaltningsteknologi. Termiske ressurser vil, i praksis, være uendelige men stille krav til forholdvis store investeringer i teknologi med forholdsvis lang levetid.

I dette prosjektet vil vi studere det komplekse samspillet mellom;

- dyphavsressursen, enten den er fornybar eller ei;
- anvendelsen av foreliggende teknologi i hhv. eksplorasjon og produksjon;

- innovasjon innen eksplorasjons- og produksjonsteknologi; og
- ressursmarkedet.

Dette er et samspill som i stor grad er preget av ulineære feedback-prosesser, av store forsinkelser og av betydelig usikkerhet. Vi foreslår derfor å nytte systemdynamikk, altså datamaskinell modellering og simulering i studiet av komplekse, dynamiske systemer, som metode på dette området.

Innen dette prosjektet vil vi gjennomføre et modell-basert studium av de naturgitte, teknologiske, forsknings- og utviklingsmessige og økonomiske forutsetningene må ligge til grunn for en fremtidig samfunnsutvikling i Norge basert på dyphavsressurser. En slik modell vil danne utgangspunkt for utvikling av en strategi, område-spesifikke policies og beslutningstaking innen innovasjonsbasert utnyttelse av dyphavsressurser på nasjonalt, regionalt og virksomhetsnivå. PhD kandidat Lars Kristian Lunde Trellevik, Norge, er nylig tilsatt i dette prosjektet.

3.5.7 Modell-basert analyse av helse, vekst og overlevelse i marine miljø

I et samarbeid med Gruppen for fiskeri-økologi og akvakultur, Mat Nat fakultetet, ble GSD tildelt en fakultetsfinansiering for videreføring av en modell-basert analyse av sammenhengen mellom fiskehelse og et bærekraftig havbruk. Prosjektet tar sikte på å avdekke sammenhengen mellom en rekke faktorer i fiske-oppdrett som påvirker fiske-helsen og, derigjennom, vekst og overlevelse i oppdrett. Analysen vil utnytte systemdynamisk modellering, simulering og analyse, og er basert på en patentert metode for analyse av et omfattende biologisk materiale som samles inn fra en rekke oppdrettsanlegg langs Vestlandskysten.

3.6 Virksomhetsfinansierte prosjekter

3.6.1 Teori, metoder, teknikker og verktøy for modellering, analyse og optimalisering av komplekse dynamiske systemer og for formidling av systeminnsikt.

GSD samarbeider på dette området med isee Systems, USA, produsenten av programvaren Stella Architect. Dette er et 12-årig samarbeid som har ledet til at mange av de metoder og teknikker som er utviklet i ved SDG, er implementert i denne verktøykassen. Dette gjelder verktøy for;

- systemanalyse med det siktemål å identifisere dominante strukturelle elementer i systemer og endogene endringer i slik dominans;
- optimering med det siktemål å validere modeller (parameter-estimering etc.) og identifisere prinsipper for god ledelse av systemer.

P.t. gjennomføres et prosjekt der vi utvikler og kombinerer en rekke avanserte analyse- og optimeringsverktøy i strukturering av og mønstergjenkjenning i store datamengder. Dette arbeidet ventes å lede fram til identifisering av kausale mekanismer som gjør at DNA kommer til uttrykk i produksjon av proteiner og spesialisert celle-dannelse i utviklingen av

organismer. Fremst i dette arbeidet ved isee Systems står en av våre doktorgradskandidater, William Schoenberg, USA, som finansieres av isee Systems.

3.6.2 Bærekraftig utnyttelse av landområder gjennom planlegging basert på en syntese av systemdynamikk og geografiske informasjonssystemer

GSD samarbeider med KnowlEdge srl (https://www.ke-srl.com), etablert og ledet av dr. Andrea Bassi, en av våre tidligere Ph D kandidater. KnowlEdge srl tilbyr modell-baserte studier av bærekraft til land og regioner verden over. Eksempelvis KnowlEdge srl bak den systemdynamiske modellen som ble lagt til grunn for UNEP sin Green Economy Report 2011 (https://naturalsciences.ch/service/publications/76477-unep-green-economy-report-2011).

Prosjektet understøtter regional arealplanlegging i fire dimensjoner gjennom å kombinere tids-dimensjonen i systemdynamisk modellering med de romlige tre dimensjonene, representert i Geografiske Informasjons Systemer (GIS). Formålet med introduksjonen av tids-dimensjonen i dette prosjektet, er å styrke vektleggingen av langsiktig ***bærekraft i arealplanlegging***. Fremst i dette arbeidet står en av våre doktorgradskandidater, Georg Pallaske, Tyskland, finansiert av KnowlEdge srl.

3.7 Eksternt, offentlig finansierte prosjekter

3.7.1 Latvia-finansierte prosjekter

GSD har, i en årrekke, samarbeidet med Riga Technical University omkring nasjonale omstillingstiltak i Latvia, - hovedsakelig energi-omstilling og utviklingen av en bio-økonomi. Prosjektene i dette samarbeidet har vært finansiert gjennom den norske del av EAA-programmet.

Som et resultat av dette samarbeidet, finansierer nå den Latviske stat et 3-årig prosjekt for modell-basert analyse av de omstillingstiltak Latvia må gjennomføre for å nå bærekraft-målene landet har forpliktete seg til overfor EU. GSD er representert i styringsgruppen for dette prosjektet og bidrar aktivt i planlegging og gjennomføring.

3.7.2 Italia-finansierte prosjekter

GSD samarbeider med Universitetet i Palermo om en ***dobbelt doktorgrad*** i systemdynamikk og modell-basert ledelse i den offentlige sektor. Studiene stipendfinansieres av den italienske stat. Så langt har to kandidater forsvart sine avhandlinger innen rammen av dette programmet, - begge innen bærekraft-paradigmet (med fokus på sikre hhv. et robust landbruk i Guatemala i lys av klimaendringer og en robust behandling av mental helse i amerikanske fengsler). Tre studier, finansiert på samme måte, er nå i gang:

3.7.2.1 Betingelser for bærekraftig kommersialisering av teknologier for karbon-fangst, lagring (CCS) og utnyttelse i olje-produksjon (EOR)

I dette forskningsprosjektet undersøkes det dynamiske bærekraft-aspektet ved kommersialiseringen av teknologier for fangst, lagring og utnyttelse av karbon (CO_2) i oljeproduksjon i

USA. I dag er kostnadene ved CCS for høye til å bli kompensert av innsparing av utslippsavgifter. Det innebærer at den private sektoren ikke finner det lønnsomt å investere i CCS. Det blir hevdet at bruken av CO_2 i forsterket oljeproduksjon (Enhanced Oil Recovery, EOR) er en potensiell kilde til inntekter fra CCS som kan kompensere ytterligere for CCS kostnader, - gitt at det foreligger en stigende læringskurve og muligheter for stordriftsfordeler. Studien integrerer operasjonell kunnskap om CCS og EOR i en tekno-økonomisk modell som kopler de to industriområdene. Modellen nyttes til å studere utviklingstrender for utbredelse av CCS under ulike scenarier vedr. olje-pris, klimapolitikk (herunder avgifter) og teknologi-utvikling og -bruk (herunder kostnadsantakelser). Utviklingstrendene gir innsikt i effekten av en avgiftspolitikk på et CO_2 marked basert på CCS/EOR. Ph D kandidat Edoard Romanenko, Russland, er stipendiat i dette prosjektet.

3.7.2.2 Finansielle og fysiske betingelser for et bærekraftig råoljemarked

I dette prosjektet gjennomføres en modell-basert studie av sammenhengen mellom olje-produksjonspolitikken i Venezuela og OPEC. I prosjektet blir investeringsfunksjoner og -beslutninger utenfor OPEC identifisert, - under antakelser om OPEC´s strategi. Dessuten identifiserer studien en optimal produksjonspolitikk for OPEC, - gitt usikkerheten som er knyttet til den produksjons- og konsum-teknologiske utvikling og foreliggende ressurs-begrensinger. Ph D kandidat Omar Chique, Venezuela, er stipendiat i dette prosjektet.

3.7.2.3 Betingelser for et bærekraftig system for ivaretakelse av folkehelsen i Lombardia (Italia) med fokus på kroniske sykdommer

I dette prosjektet gjennomføres en modell-basert studie av en ny politikk for overvåking og behandling av kronisk syke i Lombardia. Siktemålet med denne politikken er å identifisere mennesker i et tidlig stadium av kronisk sykdom, iverksette behandling på dette stadium og, ikke minst, tilby disse pasientene en tett oppfølging med det siktemål å forsinke deres sykdomsprogresjon, bedre deres livskvalitet og forlenge deres levetid. I prosjektet gjøres betingelsene for å nå dette siktemålet på en bærekraftig måte til gjenstand for et inngående studium. Ph D kandidat Olga Tolmachova, Ukaraina, er stipendiat i dette prosjektet.

3.7.3 Sveits-finansierte prosjekter

3.7.3.1 Model-basert verdikjede-analyse av Industry 4.0 prosjekter innen bærekraftige energi-transformasjonsprosesser.

GSD samarbeider med Bern University of Applied Sciences (BFH), Sveits, i et prosjekt vedrørende modell-basert analyse av verdi-kjedene i energiforsyningsselskaper som aspirerer mot en bærekraftig Industry 4.0 standard (https://en.wikipedia.org/wiki/Industry_4.0), - og det i et marked som gjennomgår betydelige omstillinger. BFH finansierer en av våre doktorgradskandidater, Dovood Qorbani, Iran, i dette prosjektet.

3.7.3.2 Model-basert analyse og ledelse av omstillingsprosesser i bygningsindustrien

GSD har et samarbeid med University of Applied Sciences, St Gallen (FHS St. Gallen), Sveits, i et prosjekt omkring omstillingsledelse i bygningsindustrien med det siktemål å utvikle et samvirke mellom offentlig politikk og bærekraftige bedriftsmodeller. Omstillingsledelse har de senere årene fremstått som en refleksiv ledelsesform som er basert på medvirkning fra interessenters side (stakeholder participation). Slik ledelse anvendes ofte i regionale utviklingsprosesser som gjennomføres inne rammen av et bærekraftsperspektiv der marko-dynamikk på et system-nivå sees i lys av mikro-dynamikken som genereres på virksomhetsnivå. Konkret studerer man hvordan en politikk for offentlige innkjøp, avfallshåndtering, CO2 regulering og arealplanlegging innvirker på utviklingen av alternative bedriftsmodeller i Sveits. Til dette nyttes en simuleringsmodell som blir utviklet, validert, analysert og anvendt av et utvalg av material-intensive bygningsfirma, NGO´er, politiske organisasjoner og industri-foreninger. Systemdynamikk nyttes derved som en strukturerende og integrerende metode i prosjektet og i gjennomføringen av scenario-analyser med det formål å utvikle en strategi som leder en ressurskrevende industri inn i en bærekraftig utvikling. Prosjektet bidrar både med et kort- og et langsiktig omstillingsperspektiv, understøtter vurderingen av omstillingstiltak og stimulerer til en sosial læringsprosess blant deltakerne. Det sveitsiske forskningsrådet (#73 – Sustainable Economy) finansierer vår Ph D kandidat. Daniel Kliem, Sveits, som deltar i dette prosjektet.

3.7.4 Pakistan-finansierte prosjekter: Analyse av betingelsene for private bedrifters finansielle bærekraft

GSD har et samarbeid med The Woman University, Multan, Pakistan, og Oslo MET innen finansiell analyse. I dette prosjektet finansieres vår doktorgradskandidat Aima Khan, Pakistan, gjennom et statlig stipend-program, for å studere fundamentale prinsipper for en bærekraftig investering i, finansiering av og utbytte-fordeling blant eierne av private bedrifter, - basert på mikro-økonomisk teori. Dette er et modell-basert forskningsarbeid som har som formål å nå fram til prinsipper for utvikling av bedrifts-finansiell strategi og taktikk med det siktemål å maksimere en bedrifts verdi over tid.

3.7.5 Malaysia-finansierte prosjekter: Matvaresikkerhet i Malaysia

GSD har et samarbeid med Universiti Putra Malaysia omkring en modell-basert studie av matvaresikkerhet. Malaysia står overfor betydelige utfordringer når det gjelder å skaffe mat til en stadig voksende og krevende befolkning. Samtidig må Malaysia reetablere en utarmet base av ressurser for matvareproduksjon. Dette innebærer et behov for å intensivere matvareproduksjonen på en bærekraftig måte. Et eksempel på dette er å kombinere risproduksjon med fiskeoppdrett (i rismarkene), - der rismarkene gir gode levevilkår for fisk og der fisken bidrar til å gjødsle rismarkene.

Sammen med Universiti Putra Malaysia, finanansierer det malaysiske undervisningsdepartementet og Southeast Asian Regional Center for Graduate Study and Research in Agriculture en av våre doktorgradskandidater, Emmy Farah Binti Alias, Malaysia, sitt studium av pro-

sesser som driver utbredelsen av slike bærekraftige intensifiseringstiltak, - herunder betingelsene for at slike tiltak skal virke økonomisk og sosialt tilfredsstillende for bøndene. Modellen som er under utvikling i dette prosjektet, skal gjøre det mulig å vurdere betingelsene for anvendelse og effekten av slike tiltak, - herunder den optimale plasseringen av slike tiltak langs en tidslinje.

4. Undervisning og internasjonalt undervisningssamarbeid

4. 1 Bachelorprogram

Ved fakultetet fikk vi, i forrige dekan-periode, administrativt godkjent våre planer om å etablere en tverrfaglig bachelor-grad med systemdynamikk som en «major». Men fakultetsledelsen har ikke tatt initiativ til å realisere disse planene til tross for at rektor var villig til å vurdere en bro-finansiering for et slikt studium. I den forbindelse sendte Prof. John D. Sterman, MIT, en uttalelse om betydningen av et slikt initiativ (se vedlegg 6).

Som beskrevet i avsnitt 5.4, er det nå tatt initiativ til et strategisk ERASMUS + program med det siktemål å etablere en tverrfaglig MOOCs-basert bachelor-utdanning i Europa med vekt på SDGs langs de samme retningslinjene vi foreslo lokalt.

4. 2 Masterprogram

Med sitt master og Ph D program, ansees GSD som et internasjonalt senter for utdanning innen systemdynamikk. GSD tilbyr to masterprogram;

- ett internasjonalt M. Phil program, Bergensprogrammet, opprettet i 1995 etter initiativ fra Universitetsdirektøren;
- ett europeisk flergradsprogram, European Masters programme in System Dynamics. (EMSD).

4.2.1 Bergensprogrammet (https://www.uib.no/fg/dynamikk#)

Programmet i Bergen er engelsk-språklig og har, i løpet av 24 år, utdannet om lag 400 masterstudenter, - i all hovedsak utenlandsstudenter rekruttert med bachelorgrad i samfunnsfag, inkl. bedriftsledelse, og naturfag, inkl. ingeniørfag. Sett i lys av at vi ikke har et rekrutterende Bachelor-program i bunn, har søknaden til studiet vært svært tilfredsstillende.

P.t. er programmet organisert i 3 semester med kursarbeid (9 kurs á 10 studiepoeng) og en masteroppgave på ett semester. Programmet i Bergen er innrettet mot systemdynamikk generelt; modellering, simulering, analyse, og formidling av kunnskap om komplekse, dynamiske systemer i form av interaktive læremiljø.

I all hovedsak er temaene for kursene knyttet til anvendelser av systemdynamikk i analyse av ***bærekraft-målene***; forvaltning av naturressurser i bred forstand, matvareproduksjon og -

sikkerhet, helse, utdanning, miljøvern, næringsutvikling, nasjonal utviklingsplanlegging, samt modellbasert utvikling, implementering og evaluering av strategier, virkemidler og beslutninger, ekspert- og interessent-medvirkning, og formidling.

Så langt tilbys ett av våre kurs som en MOOC. Ettersom vi arbeider med interaktive læremiljøer både som virkemiddel og som tema i undervisningen, - er vi på full vei mot å utvikle en kursportefølj som i stor grad vil være digitalisert. (Mer om dette i avsnitt 5.4).

4.2.2 European Masters in System Dynamics EMSD (http://europeansystemdynamics.eu)

EMSD ble opprettet 2009, og tilbys i samarbeid med Radboud University, Nederland, NOVA University, Lisboa, Portugal, og University of Palermo, Italia. Dette programmet har, inntil nylig, vært støttet av EU i form av et ERASMUS MUNDUS program og har utdannet ca 200 studenter. Iflg. en tracer-studie gjennomført nylig er 40% av studentene fortsatt i akademiske stillinger eller ansatt i forskningsinstitusjoner. Det er grunn til å tro at dette også gjelder studentene som utdannes i Bergensprogrammet. Dette gjenspeiler seg også i rekrutteringen av eksternt finansierte kandidater til vårt eget Ph D program.

I dette programmet gjennomfører alle studentene sitt første semester og 30% av dem sitt fjerde semester i Bergen. I andre semester kan studentene spesialisere seg i anvendelse av systemdynamikk i offentlig forvaltning (Palermo) eller bærekraft-studier (Lisboa). I tredje semester forbereder studentene sine oppgave-arbeider og de trenes i Group model building og Community-based system dynamics (Nijmegen), altså det å modellere i felt. I andre og tredje semester står altså praksis-arbeid sentralt. Fjerde semester bruker studentene på masteroppgavene sine ved et lærested de finner interessant, - et partneruniversitet eller et universitet utenfor Europa som er knyttet til ESMD programmet.

4. 3 Ph D program

Helt sentralt i Gruppen for systemdynamikk sitt utdanningstilbud står Ph programmet som har bred internasjonal oppslutning, - hovedsakelig fra kandidater med ekstern finansiering. Programmet er rettet mot forskning innen systemdynamisk teori, metode, teknikker og verktøy (programvareutvikling) og modell-basert analyse av problemstillinger som faller innen bærekraft-begrepet.

GSD er en av samarbeidspartnerne i et nytt kurstilbud på Ph D nivå ved UiB: Ph D for innovation: Interdsciplinary problems solving and creativity (http://phdforinnovation.com). Utgangspunktet er behovet for kreative løsninger på de bærekraftutfordringer som Agenda 2030 representerer i form av SDGs og deres samvirke.

Tabellene over 20 utdannede kandidater og 16 kandidater under utdanning taler for seg selv, både mhp; - yrkesvalg (for dem som har disputert); - bærekraft-orientering i valg av forskningstema og yrke; - internasjonal bredde; og - variasjon i kilde til (ekstern) finansiering.

For tiden arbeider alle som er uteksaminert med tema som omfattes av SDGs, - herunder miljø-orientert nasjonal planlegging og utviklingsarbeid, infrastruktur-analyse, krisehåndtering i lys av klima-endringer, nasjonal- og delingsøkonomi, og helse og utdanning i klima-utsatte områder av verden.

20 Ph D kandidater utdannet 2002 - 2018

Navn (kjønn, disp. år)	Tema	Finansiering	Nasjon	Yrke
M. M. Saleh (M 2002)	Systemdynamisk analyse metode	Kvote-stipend	Egypt	**Professor** Kairo University, Egypt (https://scholar.cu.edu.eg/?q=saleh/)
A. Sawicka (F, 2004)	Informasjons-sikkerhet	Kristiansand kommune	Polen	Nasjonal Kommunikasjonsmyndighet (https://www.nkom.no)
M. Milrad (M, 2006)	Modell-basert media-teknologi	Svensk statsstipend	Brazil	**Professor** Linnaeus Universitetet , SE (https://lnu.se/en/staff/marcelo.milrad)
S. Arango (M, 2006)	Eksperimentell økonomi: Analyse av olje-markedet	Kvote-stipend	Colom-bia	**Professor** National University, Medellin **Senior Research Fellow** EfD Colombia (https://efdinitiative.org/about-efd/people/arango-aramburo-santiago)
D. Wheat (M, 2007)	Modell-basert økonomiutdanning	Wheat Resources	USA	**Professor:** a. UiB (emeritus), https://www.uib.no/en/persons/David.Wheat b. ISM, Lithauen https://www.ism.lt/node/3484 c. NaUKMA, Ukraina. http://finance.ukma.edu.ua/en/vikladachi/2011-05-07-23-00-03/vikladachi/vit-aira-devid
J. Wiik (M, 2007)	Nasjonal Informasjons-sikkerhet	Høgskole-finansiert, Agder	Norge	Deloitte **Partner** https://www2.deloitte.com
A. Qureshi (M, 2008)	National utviklings-planlegging med vekt på National Accounting Matrix	Kvote-stipend	Paki-stan	**Asc. Professor** Oslo MET https://www.oslomet.no/om/ansatt/muhaqu/
S. Kharib (M, 2008)	Landskapsplanl.. Gjennom koplede GIS og SD modeller	Kvote-stipend	Egypt	**Senior Urban Designer** Dar Al Riyad Group, Saudi Arabia http://www.daralriyadh.com/en/
M. Pedercini (M,2009)	Modellbasert utviklings-planlegging	Millennium Institute	Italia	**Vice President & Chief Operating Officer**

				Millennium Institute: NGO innen offentlig bærekraftplanlegging: https://www.millennium-institute.org
A. Bassi (M. 2009)	Modellbasert analyse av energiomstilling på ulike aggregeringsnivåer	Millennium Institute	Italia	**CEO** KnowlEdge Srl : Rådgiver innen offentlig bærekraftsplanlegging: https://www.ke-srl.com
J. P. Ansah (M, 2009)	Gjeldsakkumulering og fattigdomsfellen i Afrika	Kvote-stipend.	Ghana	**Assistant Professor & Research Fellow** DUKE - National University of Singapore (NUS) Medial School, Health Services and Systems Research http://rc4.nus.edu.sg/fellows/john-pastor-ansah/
J. Radianti (F, 2010)	Det svarte market for datasikkerhet	Høgskole-stipend, Agder	Indo-nesia	**Forskningsleder** **CIEMlab** Senter for Integrert Krisehåndtering Universitetet i Agder https://home.uia.no/jaziarr/index/
Y. Qian (F, 2010)	Datasikkerhets-utfordringer ved automatisering av norsk sokkel	Høgskole-finansiert, Agder	Kina	**Asc. Professor** Shanghai University http://www.shu.edu.cn
M. Saldariaga (F, 2011)	Pedagogisk anvendelse av systemdynamikk I naturfag	Kvote-stipend	Colom-bia	**Ass Professor & Department Chair** Departm. of Mathematics and Nat Sci., American University of Irak https://auis.edu.krd/maria-saldarriaga-assistant-professor-mathematics-and-natural-sciences-department-chair
S. Derwich (M, 2012)	Patentrettigheter i matvareproduksjon; Forsterket mais i det sørlige Afrika	CGIAR	Tysk-land	**Forsker** Business Application Research Centre www.barc-research.com
J. Hartwig (M, 2017)	Målkonflikter mellom patentretten, vekst og konjunktur.	Frauenhofer Universitets-stipend	Tysk-land	**Senior Economist** MFive GmbH Mobility, Futures, Innovation, Economics https://www.m-five.de https://www.linkedin.com/in/johannes-hartwig-942078b1/?locale=zh_CN

A. Gerber (M, 2017)	Agriculture-based food security in South Sahara Africa: Central policies and local adaptation.	NFR stipend	Sveits	**Post Doctoral Fellow** Department of informatics Sustainability Research Group, University of Zürich https://www.ifi.uzh.ch/en/isr/people/people/gerber.html
D. Lara Arango (M, 2018)	Eksperimentell økonomi: El. kraftmarkedet og kraftoverføring	Kvote-stipend	Colom-bia	**Seniorkonsulent** Business Intelligence Webstep https://www.webstep.no/ansatt/david-lara-arango/
H. Hurrera (M. 2018)	Bærekraft i sosio-økologiske systemer under klima-skifte	Palermo universitets-stipend	Guate-mala	**Specialist Consultant** a. Department for Business, Energy & Industrial Strategy https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy b. UNEP https://www.unenvironment.org
Y. J. Lee (F. 2018)	Mental sykdom fanger I California; - behandling og bærekraft.	Palermo Universitets-stipend	Malay-sia	**Postdoctoral Fellow** Universitetet i Agder

16 Ph D kandidater under utdanning

Navn (kjønn, est. disp. år)	**Nasjonalitet**	**Finansiering**	**Tema**
S. Hackett (M, 2019)	Norge	Universitets-stipend	Analyse av integrerte evalueringsmodeller (integrated assessment models (IAMs)) i lys av klima-endringer.
A.S. Abdel-Afou (M.2019)	Palestina	Høgskole-stipend, Ålesund	Agent-basert modellering for forvaltning av oppdrett i åpne marine miljø
S.M.Blanco (M, 2019)	Spania	Universitets-stipend	Malaria, - en modell-basert analyse av den epidemiologiske utvikling i Kenya og Etiopia.
A. Tadesse (M, 2019)	Etiopia	Kvote-stipend	Teori, metoder, teknikker og verktøy for utvikling og evaluering av modell-baserte interaktive læremiljø

E. Romanenko (M,2019)	Russland	Palermo Universitets-stipend	Betingelser for bærekraftig kommersialisering av teknologier for karbon-fangst, lagring (CCS) og utnyttelse i olje-produksjon (EOR).
O. Chique (M, 2020)	Venezuela	Palermo Universitets-stipend	Finansielle og fysiske betingelser for et bærekraftig råoljemarked.
O. Tolmachova (F, 2020)	Ukraina	Palermo Universitets-stipend	Betingelser for et bærekraftig system for ivaretakelse av folkehelsen i Lombardia (Italia) med fokus på kroniske sykdommer.
A. Khan (F, 2020)	Pakistan	Pakistansk stipend	Analyse av betingelsene for private bedrifters finansielle bærekraft.
E. F.B. Alias (F, 2020)	Malaysia	Malaysisk stipend	Matvaresikkerhet i Malaysia: Co-farming av ris og fisk.
W. Schoenberg (M, 2020)	USA	Isee Systems	Teori, metoder, teknikker og verktøy for modellering, analyse og optimalisering av komplekse dynamiske systemer og for formidling av systeminnsikt.
G. Pallaske (M, 2021)	Tyskland	KnowlEdge Srl.	Bærekraftig utnyttelse av landområder gjennom bedre planlegging basert på en syntese av systemdynamikk og geografiske informasjonssystemer.
D. Qorbani (M, 2021)	Iran	Sveitsisk Høgskole-stipend Bern	Model-basert verdikjede-analyse av Industry 4.0 prosjekter innen bærekraftige energi-transformasjonsprosesser.
A. Aguilar (F, 2021)	Colombia	CoCreate (Horizon 2020)	Co-Create (Horizon 2020): En modell-basert studie av overvekt og holdninger til overvekt blant ungdom, matvareprodusenter og myndigheter i Europa.
D. Kliem (M, 2021)	Sveits	Nat Research Progr. 73; Sustainable Economy	Model-basert analyse og ledelse av omstillingsprosesser i bygningsindustrien.
B. Wilkerson (F, 2021)	USA	Universitets-stipend	Modell-basert evaluering av grønn-blå infrastrukturtiltak i urbane miljø.
L-K. L. Trellevik (M, 2021)	Norge	Universitets-stipend	Dyphavsressurser – bærekraftig innovasjon, eksplorasjon, produksjon.

4.4 Øvrig internasjonalt undervisningssamarbeid

I Bergensprogrammet (det lokale masterprogrammet) samarbeider GSD med en rekke partnere som bidrar til å styrke undervisningen. På den måten blir undervisningen aktuell, relevant og inspirerende. Videre bringer disse partnerne gjestestudenter med domenekompetanse til Bergen for spesialisering. Samspillet mellom regulære studenter og gjestestudenter skaper en gjensidig berikelse av miljøet.

4.4.1 Millennium Institute (MI) (NGO), USA

I 2003 inngikk SDG en samarbeidsavtale om forskning og utdanning med Millennium Institute (MI) (NGO), Washington D.C. (https://www.millennium-institute.org). MI gjennomfører modell-baserte analyser med henblikk på SDGs for en rekke nasjonale myndigheter verden over. I kurset GEO-SD 321, Modell-basert sosio-økonomisk planlegging, gir lederen ved for forskning og utvikling ved MI, dr. Matteo Pedercini (utdannet ved GSD), en fire ukers intensiv innføring i bruk av Threshold 21 (T21), - rammemodellen som anvendes som utgangspunkt for MIs globale arbeid. I den forbindelse bringer MI opp til 15 gjestestudenter fra ulike nasjonale myndigheter til kurset for spesialisering her i Bergen.

4.4.2 isee Systems, USA

isee Systems, USA (https://www.iseesystems.com) har implementert GSD sine prinsipper for utvikling og bruk av web-baserte interaktive læremiljø (Interactive Learning Environments - ILEs) i programvaren Stella Architect. Dette tillater oss å realisere en sømløs arbeidsprosess sfra modellering, simulering og analyse til web-basert formidling i form av ILEs. Det er denne teknologien vi nå gjør bruk av både i klasserom, i oppgaveløsning (case studies) og i MOOCs som vi tilbyr ved UiB så vel som på nettet.

Isee Systems´ programvareutvikler på dette feltet, William Schoenberg (utdannet ved SGD), tilbyr hvert år en 3 ukers intensiv innføring i utvikling av interaktive læremiljø som ledd i kurset GEO-SD 309, Model-based Interactive Learning Environments. Dette følges opp med prosjektoppgaver som studentene presenterer ved slutten av semesteret, - da gjerne i form av én- eller flerbruker-spill og ofte av så stor pedagogisk verdi at de inkorporeres i vår undervisning.

4.4.3 DIKU: Ukraina

Siden 2012 har Gruppen for systedynamikk v/ professor David Wheat (nå emeritus), gjennom flere prosjekter finansiert av SIU/DIKU, utviklet et nært samarbeid med National University of Kyiv-Mohyla Academy (NaUKMA) og Ivan Franko University of Lviv i Ukraina. Samarbeidet er sentrert omkring modell-basert undervisning i økonomi. Siktemålet har vært å styrke den langsiktige økonomiske bærekraften i Ukraina. Nasjonalbanken i Ukraina deltar i samarbeidet, og med sin geopolitiske betydning er prosjektet besøkt ved to anledninger av hhv. *statsminister Solberg* og *utenriksminister Eriksen Søreide*. Mellom UiB og NaUKMA er

det nylig inngått en avtale om felles doktorgradsutdanning (dobbeltgrad) i systemdynamikk. Prosjektet er nå forlenget med finansiering ut 2021.

Resultatene av dette samarbeidet er omfattende:

- Det er etablert ett lavere grads kurs og to høyere grads kurs i økonomisk modellering ved NaUKMA. 8 andre kurs er basert på modell-baserte pedagogiske prinsipper utviklet ved GSD.
- Mer enn 100 BA, MA og Ph D studenter og stabsmedlemmer har gjennomført minst ett semesters utdanning i Bergen, etterfulgt av videre opplæring i Ukraina.
- En makro-økonomisk simuleringsmodell for Ukraina er i stadig videreutvikling som ledd i dette samarbeidet.
- NaUKMA tilbyr ett MOOCs-basert kurs innen fagområdet.
- 3 doktorgrader er blitt avlagt basert på systemdynamiske anvendelser i økonomifaget, - ytterligere 4 arbeider er på gang.
- Systemdynamisk metode har vært i bruk i over 24 ferdigstilte masteroppgaver ved NaUKMA.
- I 2018 ble en forskningskonferanse med tittelen; «System dynamics modeling for public and corporate finance: Background and opportunities» avholdt ved NaUKMA;
- Mer enn 68 vitenskapelige artikler er skrevet som et resultat av dette samarbeidet;
- Representater fra NaUKMA og Lviv har deltatt de 6 siste årene ved International System Dynamics Conference, - og da med i alt 12 presentasjoner;
- 3 monografier er blitt publisert og en rekke workshops er blitt avholdt;
- The Ukrainian System Dynamics and Econometric Center of Excellence er blitt opprettet ved NaUKMA.

4.4.4 DIKU: Nord Dakota, USA

Som ledd i et DIKU-finansiert samarbeid med University of North Dakota (UND), inngikk UiB i 2013 en avtale med UND. Representanter fra UND, under ledelse av hhv. provost og president, har to ganger besøkt UiB og uttrykt ønske om en utvidelse av dette samarbeidet over flere fagfelt, herunder jus og drone-teknologi.

P.t. utveksler UiB studenter med UND med hovedvekt på bruk av modellering og simulering innen folkehelse. Høsten 2018 kommer 3 studenter og en professor til Bergen for utdanning i systemdynamikk. Våren 2019 regner vi med at et tilsvarende antall studenter i Bergens-programmet vil oppholde seg ved UND.

4.4.5 Climate Interactive (CI) (NGO), USA

Climate Interactive (CI) (https://www.climateinteractive.org) er en NGO som arbeider med det formål å informere verdens befolkning, herunder interessenter og beslutningstakere, om konsekvensene av de resultatene som oppnås i klima-forhandlingene organisert etter initiativ fra FNs medlemsland. Til grunn for dette arbeidet ligger systemdynamiske simuler-

ingsmodeller som samsvarer med de modellene som klima-forskere verden over nytter. Climate Interactive har nådd svært langt med sin formidling i mange land verden over, og ønsker nå å samarbeide med GSD for å kunne tilby nett-baserte simulatorer som tillater deltakerne å innta roller som deltakere i klima- forhandlingene. GSD har, med støtte fra fakultetet, utviklet en slik simulator over C-ROADS modellen som CI bruker til dette formålet, - en simulator som vi planlegger å bruke i vår egen undervisning om klima-forhandlinger.

4.4.6 Klient-basert undervisning

I vårt nye kurs, GEO-SD325, Client-Based Modeling, møter studentene reelle internasjonale oppdragsgivere som presenterer sine problemstillinger og uttrykker sine behov for modell-basert assistanse. Studentene utfordres til å gripe fatt i disse problemene i et prosjekt der de utvikler en modell og gjennomfører en analyse med problemløsning for øye. Resultatet presenteres for oppdragsgiveren ved avslutningen av prosjektet. Blant de oppdragsgiverne vi så langt har samarbeidet med, er Flyktningehjelpen i Geneve, WWF og UNEP.

5. Fremtidsperspektiver; forskning og utdanning, samarbeid og søknader

Samtlige av de aktivitetene som er beskrevet så langt, har i seg et fremtidsperspektiv. Dette gjelder spesielt vårt samarbeid med internasjonale organisasjoner omkring SDGs, - ikke minst UNEP. Disse samarbeidsaktivitetene tar vi sikte på å videreføre og styrke. I tillegg bereder vi grunnen for de neste årene. I dette avsnittet beskriver vi noen av våre nye initiativ. Dette er initiativ vi allerede har søkt om ekstern finansiering for.

5.1 Den internasjonale systemdynamikk-konferansen

Vi er blitt tildelt ansvaret for å arrangere den internasjonale systemdynamikk-konferansen sommeren 2020, - en konferanse som normalt trekker 450 deltakere. Temaet for konferansen vil være bærekraft og behovet for omstillingsledelse på en rekke samfunnsområder.

5.2 EMSD

I januar 2019 sendte konsortiet av universiteter som tilbyr det europeiske mastergradsprogrammet i systemdynamikk (EMSD programmet omtalt i avsnitt 4.2.2) (Bergen, Lisboa, Palermo og Nijmegen), en ny søknad til EU om en årlig stipendfinansering av 20 kandidater over Erasmus Mundus programmet, - en videreføring av vårt 10-årige samarbeidet innen dette programmet.

5.3 Marie Curie

Med vår satsing på bærekraftmålene, sendte GSD, i februar 2019, en søknad til EU om finansiering av et Marie Curie prosjekt (se vedlegg 4). GSD gjorde dette som koordinator på vegne av universitetskonsortiet som tilbyr EMSD programmet, samt Riga Technical University. Prosjektet er knyttet til bærekraftsmålene og vil omfatte 15 PH D kandidater som

hver vil arbeide på tvers av disse målene sammen med en rekke ikke-akademiske samarbeidspartnere i og utenfor Europa, - herunder UNEP.

5.4 MOOC-basert undervisning og ERASMUS +

GSD har, siden 1995, vært verdensledende i utvikling og bruk av modell-baserte interaktive læremiljø. Ny programvare for modellutvikling, analyse og web-basert formidling av innsikt i komplekse, dynamiske systemer har åpnet opp for utvikling av MOOCs med et banebrytende innhold. Kurset GEO-SD 360, Natural Resource Management, er utviklet og leveres på basis av slik teknologi og er den første poeng-givende MOOC tilbudt globalt av UiB. Vi har en visjon og å forbli ledende innen digital undervisning og utvikler for tiden en rekke kurs-komponenter basert på den nye teknologien.

Som ett slikt tiltak, ser GSD et sterkt behov for en bachelor-utdanning i tverrfaglig analyse av inter-sektorielle problemer. Siktemålet vårt er å utdanne kandidater med et sterkt analytisk fundament for utvikling og evaluering av politikk som strekker seg på tvers av fagfelt og sam-funnssektorer. Det er tatt initiativ til et samarbeid mellom flere europeiske universitet i den hensikt å tilby en MOOCs-basert bachelor i systemtenkning for samfunnsendring. Initiativet ledet i april 2019 fram til en søknad om et prosjekt under EU sitt ERAMUS+ strategiske pro-gram, koordinert av UiB. Formålet med dette prosjektet er å utvikle 12 MOOCs som tilsam-men vil utgjøre kjernen i en slik nett-basert utdanning. Samarbeidspartnerne bak dette initiativet er, igjen, konsortiet av de fire universitet som tilbyr EMSD programmet samt Università della Svizzera Italiana og Riga Technical University.

5.5 Belmont Forum; University of Maryland

Med sitt prosjektforslag «COAST - Coastal Ocean Assessment for Sustainability and Transfor-mation», tok University of Maryland initiativ til et prosjekt med UiB som hovedpartner og med flere akademiske partner-institusjoner i Asia. I april 2019 ble det sendt en søknad om prosjektfinansiering til Belmont Forum som bl.a. omfatter NFR og NSF.

Formålet med prosjektet er å studere tre-fire marine områder i hhv. USA, Filipinene, Japan og India med det for øye å identifisere hva som må til for å sikre at områdene forblir bære-kraftige og danner grunnlag for en rettferdig utnyttelse av områdenes marine ressurser, - herunder hvordan så kan skje i lys av globale endringer.

5.6 NFR

I april 2019 sendte UiB, i sin rolle som koordinator, en søknad til NFR om finansiering av et forskningsprosjekt «Horizontal Collaborative Computing for Societal Negotiation Processes». Søknaden ble utformet i samarbeid med et konsortium av følgende institusjoner: ETH Zurich, Chalmers University, University of Social Sciences and Humanities (SWPS), Poland, og Tohoku University, Japan. GSD og Institutt for informasjonsvitenskap deltar som partnere ved UiB som deltar i dette prosjektet. I original-beskrivelsen av prosjektet heter det:

"To reach sustainable development goals, it is crucial to involve stakeholders in Societal Negotiation Processes (SNP) to find solutions grounded in real data, encouraging strong and lasting participation and resulting in more effective policy creation. While available public databases provide multifaceted sources of information such as on affordable energy, agricultural production, clean water or sanitation, they do not sufficiently help SNP stakeholders reach their multiple goals. Collaborative computing tools already exist, but to our knowledge, collaborative access, navigation, modification, and curation of such data leveraging combined use of tabletops and heuristics-based recommendation techniques have yet to be explored. We propose to study what recently developed horizontal collaborative computing and recommendation techniques can offer co-located participants in collaborative policy ("what-if") analysis, such as improved access for the effective navigation, overview, and (re-)use of information from public databases, and reliable suggestions to assist decision-making. This project will study how horizontal computing can enhance collaborative policy analysis in a variety of European settings for important domains such as sustainable and resilient natural resource management, including energy and farming, as well as climate change in urban planning. While the main impact of this project will be in the area of ICT and collaborative interactive systems, the project will also contribute to the theory of collaboration; especially the role of gaze and behavioral synchronization to achieve shared reality in collaboration. Besides being an HCI project, it will also address long term societal challenges and UN sustainable development goals."

5.7 Akademia-avtalen

I mai 2019 sendte GSD et prosjektforslag med vekt på SDGs innen rammen av Akademia-avtalen. Prosjektet har som siktemål å nytte en kompakt form av «Horizontal Collaborative Computing for Societal Negotiation Processes» (se avsn. 5.6) i en anvendelse som omhandler den rollen «Carbon Capture and Storage» (CCS) kan spille i energiomstillingsprosesser. Dette er tett knyttet opp til prosjektet omtalt i avsn. 3.7.2.1.

5.8 Kappa programmet

GSD samarbeider med Institutt for miljø-studier ved Masaryk University Brno, Tsjekkia, med det siktemål å søke om et langsiktig forskningsprosjekt under Technology Agency of the Czech Republic - Kappa scheme. I dette prosjektet vil det bli utviklet redskap som skal hjelpe oss å; a) forstå de sosiale mekanismene som ligger til grunn for den sårbarheten overfor de klima-endringer vil opplever i naturlig og dyrket skog; b) identifisere tiltak som leder til en effektiv tilpasning til og evnt. avbøting av konsekvensene av slike klima-endringer; og c) skape en bedre forståelse av hvilke tiltak som kan gjennomføres for å øke skogens evne til å fange og lagre karbon. I studien vil det bli fokusert på Tsjekkiske skoger, men en kan se for seg at det blir gjort en tilsvarende studie i Norge som kan danne grunnlag for en sammenligning.

6. Avtale om arbeidsbetingelser ved fakultetet; produksjon og produktivitet

6.1 Avtale

I 2004 ble Gruppen for systemdynamikk fristilt fra Institutt for informasjonsvitenskap og administrativt knyttet til Institutt for geografi, - men da med en egen budsjettpost ved SV-fakultetet på linje med instituttene. I en avtale (se vedlegg 1) som regulerer samspillet GSD, instituttet og fakultetet, blir arbeidsbetingelsene ved GSD fastsatt. Her heter det at;

«Eventuell replassering av stillinger i forskningsgruppen for systemdynamikk er *som for alle fakultetets fagmiljø* avhengig av gruppens studiepoengproduksjon og forskningsaktivitet»!

Denne avtalen blir ignorert av fakultetsledelsen som, i fakultetsstyret, hevder at en slik avtale kan endres med et pennestrøk. Realiteten er at fakultetsledelsens manglende respekt for inngåtte avtaler vil føre til at GSD i nær fremtid blir lagt ned. Vi mener at dette er stikk i strid med UiB sin strategiske satsing på SDGs, på en helthetlig, integrert, tverrfaglig innfallsvinkel til global utvikling og på digitalisert, global kunnskapsformidling, - tre satsingsområder der Gruppen for systemdynamikk ligger i front.

I et vedtak fattet av rådet ved Institutt for geografi (vedlegg 2), fremgår det at fakultetsledelsen ansees forpliktet av inngåtte avtaler der instituttet er en part, og at GSD skal behandles på linje med fakultetets øvrige fagmiljø. Dette vedtaket er ikke blitt lagt fram for fakultetsstyret.

6.2 Bemanning, produktivitet og forholdet til fakultetet

Gruppen for systemdynamikk (GSD) omfatter 3 professorer:

- Professor Pål I. Davidsen
- Professor Erling Moxnes
- Professor Birgit Kopainsky

16 Ph D kandidater, hvorav 13 er eksternt finansierte, svarende til en årlig verdi av ca. 13 mill NOK.

Tabellen nedenfor viser produktiviteten ved Gruppen for systemdynamikk (GSD) relativt til SV-fakultetet;

- den tre-årige gjennomsnittlige produksjon av studiepoeng og Ph D kandidater som skal inngå i rekrutteringsmodellen;
- den kortsiktige produksjon av studiepoeng (2017) og Ph D kandidater (2016 – 19) som legges til grunn for driftsbevilgningen;
- driftsbevilgningen;
- publikasjonspoengproduksjon; og
- BOA-inntekter for 2016- 17.

Langsiktig produksjon av studiepoeng og Ph D kandidater per ansatt

(3-årig gjennomsnitt),

-grunnlaget for rekrutteringsmodellen:

Program	GSD	SV-fak	Relativ Produktivitet SDG / SV-fak
Master	31	17.79	**1.78**
Ph D	0.23	0.18	**1.27**

Kortsiktig produksjon av studiepoeng og Ph D kandidater per ansatt

-grunnlaget for driftsbevilgningen:

Program	GSD	SV-fak	Relativ Produktivitet SDG / SV-fak
Master	34.5	18.4	**1.88**
Ph D (2017)	0.67	0.15	**4.46**
Ph D (2018)	1.00	0.15	**6.66**
Ph D (2019)	1.66	0.15	**11.1**

Driftsbevilgning 2019 per ansatt; - en gjenspeiling av produktivitet:

År	GSD	SV-fak	Relativ Produktivitet SDG / SV-fak
2019	370 000 NOK	160 000 NOK	**2.26**

Publikasjonspoeng per ansatt:

År	GSD	SV-fak	Relativ Publiering SDG / SV-fak

2017	4.00[1)]	2.77	**1.44**

BOA inntekter per ansatt

(utover 13 mill NOK i internasjonal stipendfinansiering av Ph D kandidater):

År	**GSD**	**SV-fak**	**Relativ BOA-inntjening SDG / SV-fak**
2016	772 000 NOK	459 000 NOK	**1.68**
2017	943 500 NOK[1)]	536 000 NOK	**1.76**

1) I 2016/17 var GSD, pga sykdom, bemannet med kun to personer.

De røde tallene i tabellen over viser at Gruppen for systemdynamikk er langt mer produktiv enn fakultetsgjennomsnittet. Dette gjenspeiles i en driftsbevilgning som ligger på 2.26 ganger fakultetsgjennomsnittet. I fakultetsledelsens fremlegg til budsjett for 2019 fremgår det *helt feilaktig* at GSD «har en overdekning med 0.1 årsverk». I realiteten skyldes denne feilaktige fremstillingen at gruppen i 2004 aldri fikk med seg den «grunnbevilgningen» som ellers kommer alle andre fagmiljø til gunst gjennom deres institutt-tilknytning.

Medregnes en slik «grunnbevilgning», fremstår den faktiske underbemanningen av GSD på 1.3 ansatte. Faktum er at fakultetsledelsens beregningsmåte krever hver av de ansatte ved GSD må arbeide ca. 2.5 ganger fakultetets- gjennomsnittet, for å kunne legitimere et krav på en stilling, - som kun vi gi en avlastning på 33% for hver ansatt. *En slik forskjellsbehandling er i strid med den inngåtte avtalen og er ikke til å leve med. Arbeidsbetingelsene gjør det umulig å rekruttere kvalifiserte medarbeidere, - enten det er i en ny stilling eller til erstatning for personer som går av.*

6.3 Konklusjon

Gruppen for systemdynamikk (GSD) yter et vesentlig bidrag til UiB sin utdanning og forskning innen SDG, systemanalyse og digital undervisning. Gruppen arbeider under betingelser som er uforenlig med det bidraget gruppen yter. Ledelsen ved SV-fakultetet overholder ikke den inngåtte avtalen av 2004, gir oss ingen forutsigbarhet og forårsaker derigjennom at gruppen innen kort tid vil bli avviklet.

Det må være av strategisk interesse for UiB sin ledelse at så ikke skjer og at GSD sikres forutsigbarhet og arbeidsbetingelser på linje med UiB´s øvrige ansatte i vitenskapelige stillinger.

Sett i lys av en slik strategisk satsing, vil vi foreslå at vårt 10-årige samarbeid med våre partnerinstitusjoner i Europa, Lisboa, Palermo, Nijmegen og Riga, videreføres innen rammen av European Universities Initiative.

Vedlegger

Vedlegg 1: Avtale mellom SV-fakultetet, Institutt for geografi og Gruppen for systemdynamikk

Saksdokument 18.02.16 14:55

DET SAMFUNNSVITENSKAPELIGE FAKULTET

Arkivkode:
Sak nr.: 2004/ 6393

Fak.sak: 098/2004
Møte: 28.09.2004

AVTALE OM OVERFØRING AV FORSKNINGSGRUPPE FOR SYSTEMDYNAMIKK TIL INSTITUTT FOR GEOGRAFI

Bakgrunn
Ved Institutt for informasjons- og medievitenskap har det siden etableringen av instituttet ved årsskiftet vært ført drøftinger mellom instituttleder og den vitenskapelige staben om den faglige profilen ved instituttet. En konsekvens av disse drøftingene var at forskningsgruppen for systemdynamikk, i lys av de strategiske planene ved instituttet, ikke fant tilstrekkelige rammebetingelser til å kunne videreføre sine undervisnings- og forskningsoppgaver ved det nye instituttet. Forskninsgruppen består i dag av professor Pål Davidsen, professor Erling Moxnes og førsteamanuensis Ali Kerem Saysel.

På grunnlag av dialog mellom forskningsgruppen, institutt- og fakultetsledelse var det enighet om at den beste løsningen for alle involverte parter ville være om forskningsgruppen kunne føre samtaler med andre aktuelle fagmiljø ved fakultetet med sikte på en eventuell overføring av stillinger, undervisningsopplegg og forskningsoppgaver. Forskningsgruppen var i samtaler både med Institutt for geografi og Institutt for økonomi. Konklusjonene på disse drøftingene var at det var grunnlag for en overføring til Institutt for geografi.

Avtale om overføring
Fakultetsledelsen har med utgangspunkt i samtalene mellom Institutt for geografi og forskningsgruppen for systemdynamikk forhandlet fram forslag til avtale om overføring. Avtalen tar utgangspunkt i at eksisterende ressurser til systemdynamikk ved Institutt for- informasjons og medievitenskap overføres til Institutt for geografi, men slik at forskningsgruppen for systemdynamikk utgjør en separat budsjettenhet. Utover tilførsel av et nytt postdoktorstipend til Institutt for geografi innebærer forslag til avtale ingen ressursforsterkning til noen av miljøene:

Forslag til avtale medfører at:

- Ansettelsesforholdet for professor Pål Davidsen, professor Erling Moxnes og førsteamanuensis Ali Kerem Saysel fra Institutt for informasjons- og medievitenskap til Institutt for geografi med virkning fra 01.10.04.:
- Overføringen av stillingene skal ikke påvirke Institutt for geografi sitt ressursgrunnlag. Forskningsgruppen for systemdynamikk framstår som en separat enhet i budsjettmodellen. Eventuell replassering av stillinger i forskningsgruppen for systemdynamikk er som for alle fakultetets fagmiljø avhengig av gruppens studiepoengproduksjon og forskningsaktivitet.
- De ansatte i forskningsgruppen for systemdynamikk skal kunne velges til instituttets organer på samme måte som instituttets øvrige ansatte. Unntaket er

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for vervet som instituttstyrer som skal ha sitt utspring fra geografi. Gruppen skal være garantert observatørstatus med møte- og talerett i instituttstyret.

- Overføringen medfører at Gruppen for systemdynamikk fortsatt får disponere undervisningsarealer i rom 1030 og 1040 i Stein Rokkans hus. I 2004 foretar fakultetet utskifting av maskiner og innkjøp av flatskjermer til disse labene. Deretter tilføres gruppen årlige budsjettmidler til drift og oppgradering av utstyr etter nærmere avtale mellom instituttet og fakultetet. Instituttet får også etter nærmere avtale tilgang til pc-stuer i Ulrike Pihls hus for gjennomføring av laboratorieeksperiment.
- Ordinære driftsmidler tildeles gruppen etter de kriterier som ligger til grunn i fakultetets budsjettmodell.
- Doktorgradsstudenter knyttet til systemdynamikk vil fortsatt kunne disponere kontorarealer i 5. etasje i Lauritz Meltzers hus. Eventuelle nye doktorgradsstudenter vil få kontor ved Institutt for geografi.
- Alle budsjettmidler fordelt til Gruppen for systemdynamikk i 2004 blir overført til Institutt for geografi, herunder også lønnsmidler til studentassistanse. Belønningsmidler for aktiviteter i 2004 som først blir utbetalt i 2005 skal også overføres til gruppens budsjett.
- Gruppen for systemdynamikk får administrative tjenester levert fra fellsadministrasjon for geografi og sosialantropologi. Fakultetssekretariatet vil bistå med ressurser knyttet til internasjonale studiesaker (veiledning, opptak, innpassing) for systemdynamikk.
- Institutt for geografi tilføres en 3-årig postdoktorstilling i geografi med undervisningsplikt.

Styret ved Institutt for geografi godkjente i møte 02.09.04 forslag til avtale.

FORSLAG TIL VEDTAK:

Styret for Det samfunnsvitenskapelige fakultetet overfører ansettelsesforholdet for professor Pål Davidsen, professor Erling Moxnes og førsteamanuensis Ali Kerem Saysel fra Institutt for informasjons- og medievitenskap til Institutt for geografi med virkning fra 01.10.04.

Alf Erling Risa
dekanus

Lise Gundersen
fakultetsdirektør

20.09.04//TT

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Vedlegg 2: Behov for avklaring av prinsipper for bemanning av Gruppen for systemdynamikk

Vedtak:

Instituttrådet ved institutt for geografi har i møte 25/3 gjort følgende vedtak:

Gruppen for systemdynamikk har stor relevans for Universitetet i Bergen sine strategiske satsinger. Derfor understreker instituttrådet den rollen som Gruppen for systemdynamikk spiller i oppfyllelsen av

- fakultetets målsettinger for utdanning, forskning, og inntekter; og
- universitetets strategiske målsettinger.

Miljøet for systemdynamikk ved UIB med Masterprogrammet og doktorgradsundervisning har en unik posisjon internasjonalt, og kan bare sammenlignes med miljøet ved Massachusetts Institute of Technology. For å bevare denne posisjon og ivareta både de omfattende faglige aktiviteter, og hensynet til HMS- og HR-perspektiver og rettigheter for gruppens forskere, er det behov for forutsigbarhet for bemanningen for årene som kommer.

Som det fremgår av Vedlegg 1, er gruppen svært produktiv, men har over lang tid vært underbemannet relativt til fakultetets øvrige fagmiljø. Underbemanningen henger sammen med at gruppen har falt utenfor den rekrutteringsmodellen som benyttes ved fakultetet. Dette er uheldig for Gruppen for systemdynamikk som dermed mister forutsigbarhet og for fakultetet som må spesialbehandle gruppen. Sett på denne bakgrunnen, fremmer instituttrådet to alternative forslag til prinsipper for bemanning for gruppen for systemdynamikk og ber fakultetsstyret om å vedta ett av disse prinsippene.

1. Strategisk forankring av Gruppen for systemdynamikk

Virksomheten ved Gruppen for systemdynamikk omhandler studiet av komplekse, dynamiske systemer og er plassert helt sentralt i UiB sin strategiske satsing på ***tverrfaglighet***, ***bærekraft*** og ***digitalisering***:

Gruppen utvikler og gjør bruk av teori, metoder, teknikker og verktøy, herunder modellering, simulering og analyse, i sine studier. Videre utvikler og evaluerer gruppen strategier og prinsipper for beslutningstaking i slike systemer. Som illustrert av OECD foreligger det et betydelig behov for ***systemtenkning på tvers av fag og samfunnssektorer***:

> "Governments that have spent decades perfecting systems that can successfully manage complicated problems (such as banking regulation, trade treaties, and healthcare systems), now find themselves immersed in a world of complex problems. -- Traditional management tools have limited capabilities when applied to complex problems. For the sake of expediency, manageability, and clarity, traditional approaches simplify complex problems into what are considered to be its

constituent parts and manage them through discrete interventions, layered one on top of another. However, by looking at actors and interventions in isolation or disconnected from past efforts, complex policy legacies may fail to be captured and addressed. -- Applying a systemic lens to complex problems is useful to map the dynamic of the system underpinning it, how the relationship between system components affect its functioning, and what interventions can lead to better results. System thinking help understand how systems are structured and how they operate." (OECD, 2017, s. 12-15)[17]

Gruppen innretter sin anvendelse av systemdynamikk på ***FNs integrerte bærekraftmål*** (Agenda 2030), WHO´s helsemål ogUNEP´s mål for samspill mellom menneske og natur. Dette er mål som EU har gitt sin fulle tilslutning til i sin etterspørsel etter «policy assessment strategies, methods and tools». Gruppen gjennomfører studier innen befolkningsutvikling, landbruk, samfunnsmedisin, utdanning, økologi, ressursforvaltning herunder marine ressurser, energi og klima. Dette gjøres bl.a. i samarbeid med UNEP, Millennium Institute (NGO), Climate Interactive (NGO) og med en rekke universiteter. Gruppen bidrar i to Horizon 2020 prosjekter og to NFR prosjekt på disse feltene. En Marie Curie søknad innen rammen av Agenda 2030, koordinert av gruppen, er under behandling i EU.

Gruppen arbeider på den internasjonale utdanningsarenaen med EU- og SIU-finansierte universitetssamarbeid på master og doktorgradsnivå. I en forlengelse av dette, formidler gruppen nett-basert systeminnsikt i form av modell-baserte interaktive læremiljø (ILM) og MOOCer basert på en ***digitalisering av undervisning***. Gjennom sitt samarbeid med isee Systems disponerer gruppen et programvareverktøy som tilbyr en sømløs overgang mellom modellering og digital formidling. Gruppen ligger, med sine interaktive læremiljø, helt i forkant av digitalisert, global, og fossilfri undervisning, - ikke minst rettet mot land i utvikling. Gruppen koordinerer en Erasmus+ Strategic Partnership søknad fra seks europeiske partnerinstitusjoner, herunder tre partnere som gruppen samarbeider med i sin European Master in System Dynamics. Prosjektet vil utvikle en rekke ILM-baserte MOOCer med det siktemål å tilby etterspurt undervisning i systemtenkning og modell-basert analyse.

2. **Prinsipper for bemanning**

Når det gjelder prinsipper for bemanningen ved Gruppen for systemdynamikk tar instituttrådet utgangspunkt i "Avtale om overføring av forskningsgruppe for systemdynamikk til institutt for geografi", fra 28.09.2004 (Vedlegg 3) som sier:

"Overføringen av stillingene skal ikke påvirke Institutt for geografi sitt ressursgrunnlag. Forskningsgruppen for systemdynamikk framstår som en separat enhet i budsjettmodellen. Eventuell replassering av stillinger i forskningsgruppen for systemdynamikk er som for alle fakultetets fagmiljø avhengig av gruppens studiepoengproduksjon og forskningsaktivitet."

[17] OECD (2017). Working with change: systems approaches to public sector challenges. OECD Observatory of Public Sector Innovation. An initiative of the OECD's Public Governance and Territorial Development Directorate. Paris.

Instituttrådet ser for seg to alternative prinsipper for oppfylling av denne avtalen:

Forslag a:

Gruppen for Systemdynamikk får tildelt grunnbevilgning i rekrutteringsmodellen på linje med fakultetets institutter slik at gruppen behandles i henhold til den siterte overførings-avtalen.

- Forslaget innebærer ingen endring i budsjettmodellen, bare at den benyttes med tallmessige antakelser slik overføringsavtalen tilsier.
- Instituttrådet foreslår at gruppen skal få grunnbevilgning per ansatt tilsvarende gjennomsnittet for fakultetet.
- Instituttrådet er innforstått med at budsjettmodellen ikke skal benyttes til alloker-inger mellom grupper på instituttene; men denne begrensningen kommer ikke til anvendelse ettersom gruppen for systemdynamikk i følge avtalen skal framstå "som en separat enhet i budsjettmodellen".

Forslag b:

- Ved hver budsjettbehandling underrettes fakultetsstyret om gruppen for system-dynamikk sin faktiske produktivitet. Den skal uttrykkes i antall studentårsverk fullført og i antall PhD kandidater som har disputert (3-årig snitt per ansatt). I tråd med den reviderte rekruteringsmodellen av 11.09 2018, kan begrepet produktivitet utvides til å inkludere også andre forhold som tillegges vekt, så som ekstern finansiering og strategisk satsing. Så sammenlignes målet for produktivitet per ansatt med tilsvar-ende produktivitet for de instituttene som, ifølge rekrutteringsmodellen, ligger an til å få tildelt nye stillinger. Dersom gruppen for systemdynamikk er konkurransedyktig, tildeles Gruppen for systemdynamikk en stilling.

Begge forslag gjør administrasjonen ved fakultetet mer effektiv og ryddig, og de vil begge skape trygghet for fag og arbeidsplasser ved Gruppen for systemdynamikk. Særlig viktig er dette for prof. Birgit Kopainsky som skal lede gruppen med dens mange aktiviteter, og som skal overbevise framtidige medarbeidere om at Universitetet i Bergen er en egnet institusjon for videreføring av faget og dets bidrag til undervisning og forskning ved Universitetet i Bergen.

Vedlegg 3

UNEP prosjektet; “African Coexistence Landscapes: Securing Their Future for People, Elephants and other Wildlife”.

KAZA TfCA: “Master Integrated development Plan”.

Vedlegg 4: MARIE CURIE søknad "SDG IMPAKT"

"SDG IMPAKT: Sustainable Development Goals: Integrated Model-Based Policy Analysis and Knowledge Transfer"

Vedlegg 5

Council for Science and Technology, Government Office for Science, UK

"Computational Modeling: Technological Futures: Chapter 1; Why Model?"

Vedlegg 6

Uttalelse til rektor ved UiB fra Prof. John D. Sterman, Sloan School of Management, MIT

Vedr. behovet for opprettelse av et tverrfaglig bachelorprogram med utgangspunkt i systemdynamikk

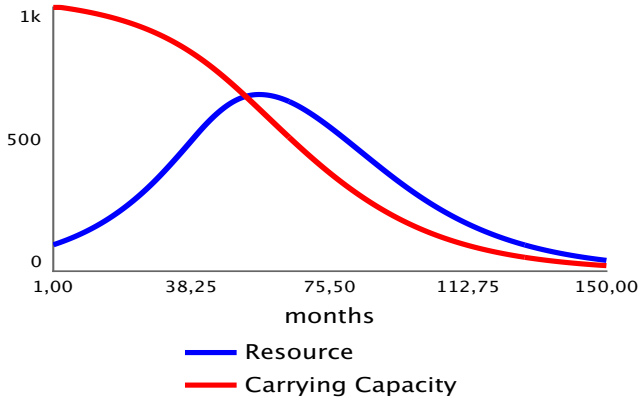

UNIVERSITAS
BERGENSIS

Gruppen for systemdynamikk (GSD)

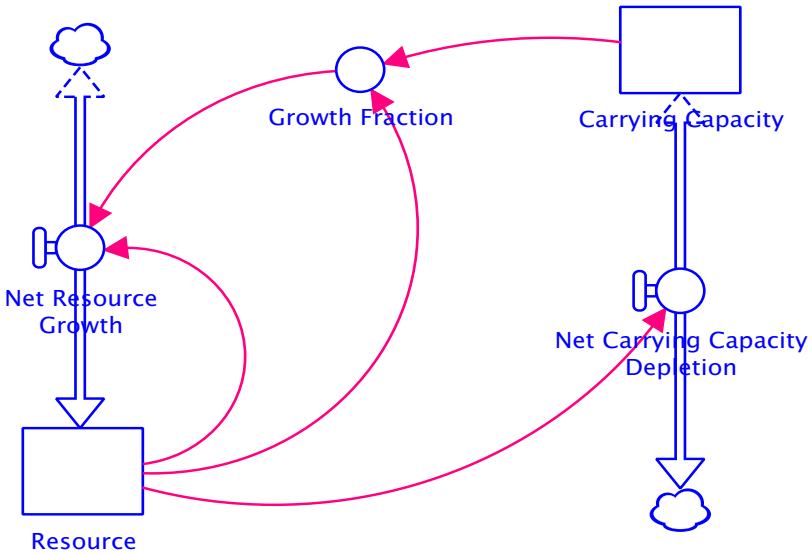
Status 1. mai 2019

An integrated perspective on SDGs
by way of
modeling, analysis and dissemination;

the dynamics



of
accumulation, feedback and nonlinear interaction



Innhold

1. Innledning

Gruppen for systemdynamikk (GSD) sprang ut av undervisning og forskning ved Institutt for informasjonsvitenskap. Som et uttrykk for fagets prominens ved UiB, ble grunnleggeren av fagområdet systemdynamikk, Prof Jay W. Forrester, MIT, oppnevnt til æresdoktor ved Universitetet i Bergen så tidlig som i 1990. I 1995 ble et internasjonalt master- og doktorgradsprogram innen fagområdet etablert etter initiativ fra Universitetsdirektøren.

Fom 2004 har gruppen vært organisert som en egen økonomisk enhet ved fakultetet og knyttet til Institutt for geografi. GSD omfatter p.t. 3 professorater og 16 doktorgradskandidater. Gruppen er det ledende forsknings- og utdanningsmiljøet i Europa på dette fagområdet og regnes p.t., sammen med MIT som ledende også på verdensbasis.

I perioden 2003 – 2020 vil 4 av gruppens tilsatte ha innehatt lederskapet i System Dynamics Society, - herunder den første kvinne. To av gruppens medlemmer er blitt tildelt hhv. forskningsprisen Jay W. Forrester Award og SDS Distinguished Service Award. En rekke studenter er, gjennom årene, blitt tildelt Donella Meadows Award for beste studentarbeid.

Arbeidsmarkedet for våre kandidater er svært gunstig. Globalt er det stor etterspørsel etter kandidater med kompetanse i integrert analyse av komplekse systemer og utvikling og evaluering av politikk på tvers av fagfelt og samfunnssektorer. Eksempelvis etterspør EU i flere av sine policy-dokument denne typen kompetanse (se avsnitt 2.). Videre påpeker Council for Science and Technology, UK Government Office of Science, i sin rapport "Computational Modeling: Technological Futures", 2018, ´på behovet for kompetanse i modellering og da med eksplisitt referanse til systemdynamikk.

Som uttrykk for hvor godt systemdynamikk egner seg som tverrfaglig metode, publiserer GSD i topp journaler innen management (*Management Science*), political science (*Journal of Conflict Resolution)*, økonomi (*Journal of Environmental Economics and Management*), medisin (*Drug and Alcohol Dependence)* og naturligvis innen systemdynamikk (*System Dynamics Review*).

Som det fremgår av en tracer-studie, innehar 65% av våre uteksaminerte PhD-kandidater ledende undervisnings- eller forskerstillinger ved høyere akademiske institusjoner, - ca. 40% av våre EMSD studenter er i akademiske rekrutteringsstillinger og en rekke av våre tidligere masterstudenter har disputert ved andre undervisningsinstitusjoner og er professorer ved universiteter verden over.

GSD har et aktivitetsnivå og en produktivitet som langt overstiger fakultetsgjennomsnittet. Bemanningen står ikke i forhold til gruppens arbeidsmengde. Arbeidsbelastningen er uholdbar. Dette skyldes at fakultetsledelsen ikke respekterer de bemanningsbetingelsene som ble nedfelt i avtalen om fristilling av GSD fra Institutt for informasjonsvitenskap (se avsn. 6).

2. Fagområdet systemdynamikk og dets anvendelse innen SDG-studier

Systemdynamikk er studiet av komplekse, dynamiske systemer som spenner over et mangfold av fagområder og samfunnssektorer. Strukturen i slike systemer utgjøres gjerne av ulineært koplede feedback-løkker, preget av tidsforbruk (forsinkelser) og usikkerhet. Resultatet er en dynamisk utvikling over tid som det ofte er vanskelig å tolke og enda mer krevende å styre.

Faget er operasjonelt og i kjernen av faget utvikler vi teori, metoder, teknikker og verktøy for modell-basert;

- kunnskapsinnsamling med ekspert- og interessent-medvirkning;
- analyse av sammenhengen mellom komplekse systemers struktur og dynamikk;
- utforming prinsipper for beslutningstaking, forankret i en overordnet strategi; og
- utvikling av interaktive læremiljø, herunder globale flere-bruker spill og MOOCs, som bidrar til formidling av innsikt i komplekse, dynamiske systemer.

Ved UiB anvendes systemdynamikk i hovedsak for å studere hvordan bærekraft-målene nedfelt i Agenda 2030 kan bli oppfylt. Spesielt analyserer vi *samvirket* mellom den politikk som legges til grunn for måloppnåelse innen de enkelte samfunnsområder (f. eks. helse, utdanning, ressursforvaltning, klima, og økonomi), - hvilke motsetninger som kan oppstå og hvilke synergier som kan utnyttes.

Målet er å utvikle simuleringsmodeller som er så realistiske og gjennomsiktige at mennesker som skal bidra til å oppfylle bærekraft-målene, gjenkjenner virkeligheten i modellene. På den måten kan de ta eierskap i modellene. Og slik sikrer vi at de strategiske og taktiske konklusjonene som arbeidet leder fram til, får gjennomslag i praktisk politikk.

Modeller nytter vi også til å *formidle* innsikt i komplekse, dynamiske systemer. Vår forskning viser at lærende kommer til dype erkjennelser ved *bruk* av slike modeller. Vi utvikler derfor interaktive læremiljøer som inkorporerer simuleringsmodeller på en sømløs måte. Slike læremiljøer tar gjerne form av globale internett-spill for flere aktører og viser seg å ha en betydelig pedagogisk effekt. Læremiljøene gir de lærende et risiko-fritt laboratorium for utprøving av egne beslutninger i form av en scenario-analyse eller i samvirke med andre beslutningstakere. Studiet av lærende under arbeid i slike kontrollerte miljøer setter oss forskere i stand til å videreutvikle vår formidlingsevne og den læringsteknologien vi gjør bruk av.

Det å satse på bærekraft-målene innebærer bl. a. at vi må rekke ut til et globalt publikum; -til våre studenter og til andre som dra nytte av vårt forskningsarbeid. I så måte spiller digitalisering og MOOCs en helt sentral rolle. Vår kompetanse i utvikling av modell-baserte interaktive læremiljøer, gir oss en internasjonal lederrolle på feltet.

Etterspørselen etter vår kompetanse knyttet til bærekraft-målene illustreres godt av de vi skriver i innledningen til vår 2019 Marie Curie søknad (SDG IMPACT):

"SDG IMPAKT – "**Sustainable Development Goals: Integrated Model-Based Policy Analysis and Knowledge Transfer" –** is intended to build capacity in the assessment of policies designed to attain the United Nations (UN) Sustainable Development Goals (SDGs) set out by Agenda 2030[1], and in effective transfer of the knowledge gained to SDG professionals, students of the SDGs, and the public at large. SDG IMPAKT will educate a cohort of 15 creative, entrepreneurial and innovate early-stage researchers (ESRs) in the:

- integrated model-based design and analysis of policies aimed at the attainment of the SDGs; and
- transfer of knowledge gained, by way of model-based innovative, interactive learning environments (ILEs), - made publicly available to strategy developers, policy designers, decision makers and, in the form of MOOCs, to SDG students and to the public at large so as to facilitate world-wide access to free education, transparency, and broad engagement in the sustainable development domain.

In Europe and elsewhere, addressing SDGs in an **integrated** way is a societal imperative of outmost importance. This has been recognized by the UN and articulated by stakeholders, scientists, politicians, administrators, and the public. The SDGs feature in all of the European Commission's 10 priorities[2]. In 2016, the European Commission outlined its strategic approach towards the implementation of the 2030 Agenda, including the Sustainable Development Goals, by declaring "sustainable development as an essential guiding principle for all European Commission policies" and by outlining the next steps for a sustainable European future [3].

The need for an integrated approach originates from the comprehensive and complex reality that the SDGs address. However, our **capacity to develop such an integrated perspective, including adequate theories, methods, techniques, and tools, remains unavailable to most professionals (strategy developers, policy designers, and decision makers), - and to the public at large.** As emphasized by Nilsson et al.[4], "Implicit in the SDG logic is that the goals depend on each other - but no one has specified exactly how. International negotiations gloss over tricky trade-offs". Moreover, the European Commission has, since the turn of the century, called for rigorous impact assessments of planned policies and actions with emphasis on long term sustainability[5] and stated, more recently, that "We should make policy choices that ensure that our various objectives are mutually reinforcing. Actions that promote competitiveness, growth, and jobs, as well as economic and social cohesion and a healthy environment reinforce each other. These are all essential components of the overarching objective of sustainable development, on which we must deliver"[6]. Finally, according to **the Operational Research Society**[7]**:** "In 2017, the UN, the World Health Organization (WHO), and the Organization for Economic Co-operation and Development (OECD) all publicly declared **systems thinking** to be a **key leadership skill** that is necessary to deal with the fundamental interconnectedness of complex, local-to-global economic, social and environmental issues". The **SDG IMPAKT will train candidates to identify precisely how the SDGs are interrelated, to communicate their findings through effective means of knowledge transfer, and to develop the systems-based leadership skills called for**.

SDG IMPAKT proposes a unique research programme on **model-based, integrated policy design, analysis, and knowledge transfer to enhance and promote a well-balanced attainment of the SDGs**. This programme is complemented by an **advanced professional training programme to strengthen ESRs´ transferable skills."**

1 UN General Assembly (2015). Transforming our world: the 2030 Agenda for Sustainable Development, 21 October 2015, A/RES/70/1. Available at: https://sustainabledevelopment.un.org/

2 https://ec.europa.eu/commission/priorities_en

3 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52016DC0739&from=EN

4 Nilsson, M., D. Griggs and M. Visbeck (2016). "Policy: map the interactions between Sustainable Development Goals." *Nature News* **534**(7607): 320.

5 https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and- how/better-regulation-guidelines-and-toolbox_

6 The Commission's Strategic Objectives 2005-2009, COM(2005).

7 **The Operational Research Society, The OR Blogs**, https://www.theorsociety.com/Blog/features/20180313124138.aspx

3. Forskning og internasjonalt forskningssamarbeid

Gruppen for systemdynamikk deltar i et omfattende forskningssamarbeid med en rekke institusjoner og med noen private virksomheter som alle har en innretning mot bærekraft-målene. Noen av disse samarbeidsprosjektene, omtalt i dette avsnittet, er finansiert av EU, ett av NFR, og flere er privat-finansierte. I avsnitt 5 omtales en rekke initiativ vi nylig har tatt til internasjonale forsknings- og undervisningssamarbeid.

3.1. HORIZON 2020 prosjekter

3.1.1 CO-CREATE (https://www.fhi.no/en/studies/co-create/):

Dette prosjektet er ledet av Folkehelseinstituttet i Oslo. 14 institusjoner fra en rekke Europeiske land, Australia og Sør-Afrika deltar. Studien «Confronting obesity: Co-creating policy with youth» omhandler en bærekraftig forebyggende helsepolitikk der vi undersøker hvordan samfunnet kan legge til rette for at ungdom velger et sunt kosthold og en aktiv livsstil. Et hovedformål er å begrense utbredelsen av «livsstilssykdommer». Systemdynamikk nyttes til å fange ungdoms egen opplevelse av livsstil, herunder forhold til kosthold og helse, i simuleringsmodeller, - modeller som så suppleres med kunnskap fra andre kilder; forskning, offentlig forvaltning, næringsliv og interesseorganisasjoner. Modellene vil bli lagt til grunn for utforming av effektive, forebyggende tiltak som bidrar til å ivareta folkehelsen. Ph D kandidat Anaely Agular, Colombia, er tilsatt i dette prosjektet.

3.1.2 SURE Farm (Horizon2020) (https://surefarmproject.eu/):

Dette prosjektet er ledet av Universitetet i Wageningen. 11 universiteter og 5 forskningsinstitusjoner fra en rekke Europeiske land deltar. Studien «Towards SUstainable and REsilient EU FARMing systems» omhandler bærekraftig matvareproduksjon i landbruket og undersøker betingelsene for en bærekraftig og motstandsdyktig produksjon av mat i EU under den usikkerhet som preger klima og samfunnsforhold (befolkningsutvikling, urbanisering etc.). Prosjektet er innrettet mot verdikjeder i matvareproduksjonen og er knyttet til programområdet: «Sustainable Food Security – resilient and resource efficient value chains». Systemdynamikk nyttes til å utvikle modeller av verdikjeder, og i utforming og gjennomføring av scenario-analyser og konsekvensvurderinger.

3.2. EU-strategiske Programmer:

3.2.1 UNEP: Africa's Coexistence Landscapes: Securing their Future for People, Elephants and other Wildlife.

Finansiering: DG ENV / DG DEVCO ENRTP-GPGC Strategic Programme.

Som ledd i vår satsing på bærekraft-målene inngikk UiB nylig en MoU med UNEP. Studien «*Africa's Coexistence Landscapes: Securing their Future for People, Elephants and other Wildlife»* (se vedlegg 3a) omhandler bærekraftig utnyttelse av afrikanske landskap som deles mellom dyr og mennesker. En bærekraftig sameksistens mellom dyr og mennesker er en betingelse for å opprettholde slike landskap, - i dette tilfellet to av de største, internasjonale landskapsvernområder i verden; Transfrontier Conservation Areas (TfCA) KAZA (Kavanga / Zambezi), delt mellom Botswana, Angola, Namibia, Zambia og Zimbabwe (se vedlegg 3b) og TfCA TRIDOM (se nedenfor).

Det er enighet i alle ledd av prosjektet;

- i FN/UNEP;
- i KAZA TfCA sekreteriatet; og
- blant de fem ministrene som utgjør den internasjonale styringsgruppen for KAZA (),

om at systemdynamikk (modellering, simulering, analyse og formidling) er den integrerende metoden som skal anvendes i dette prosjektet. Vårt arbeid med UNEP vil siden omfatte et tilsvarende TfCA, TRIDOM (Tri national Dja-Odzala-Minkebe), som omfatter deler av Cameroon, Gabon og Congo, og andre vernede områder verden over, - bl. a. India/Nepal/ Buthan, sentralasiatiske nasjoner, Brazil, Balkan og Spania.

3.3. Konsortium-finansierte prosjekter

3.3.1 The LIVES Project (https://livesproject21.org/):

Dette prosjektet, finansiert av NOMIS og MAVA, ledes av Universitetet i Geneve. Prosjektet «The Lives Project» tar for seg bærekraftig utnyttelse av naturressurser (ecosystems services) i krysningspunktet mellom mat, vann og energi og fokuserer på Cambodia og Colombia. Studiet av potensielle konflikter og mulige synergier mellom oppfyllelsen av bærekraft-mål står sentralt i prosjektet. Til dette formålet nyttes modellbasert kunnskapsinnsamling, analyse og formidling. I prosjektet deltar p.t. 6 universiteter og forskningsinstitusjoner, 3 inter-esseorganisasjoner og 1 konsulentselskap som er spesialisert i systemdynamisk modellering og analyse.

*3.3.2 **CIGIAR** (Consultative Group for International Agricultural Research) **CCAFS** (Climate Change, Agriculture and Food Security) **prosjekt***

GSD samarbeider, innen rammen av CCAFS, med prof. Chuck Nicholson, Dyson Cornell, SC Johnson College of Business, USA,i et prosjekt som omhandler gapet som foreligger i lav- og middel-inntektsland mellom anvendelsen av systemanalyse i landbruksforskning og den foreliggende bærekraft i matvaresikkerhet. Formålet er å sette en agenda for å lukke dette gapet vha. systemdynamisk modellering og analyse.

3.4. NFR-finansierte prosjekter

3.4.1 KLIMAFORSK: New Waterways - *towards water-sensitive and climate-adapted Nordic cities*

GSD deltar i et nasjonalt samarbeidsprosjekt, ledet av Norsk Institutt for Vannforskning, finansiert av NFR med fokus på bærekraftig vannforvaltning i urbane sentre. Prosjektet omhandler nye løsninger som tar oss videre fra dagens konvensjonelle urbane vannforvaltning (UVF), herunder overvannshåndtering. Ved å nytte modellering, er siktemålet å analysere hindringer og potensielle mekanismer for intervensjon. Dette ventes å gi ny kunnskap og bane veien for hvordan den nåværende norske vannforvaltningen i byer kan omdannes til et vannsensitivt og klimatilpasset samfunn. Resultatet skal hjelpe norske byer til å bli forbilder i overgangen til bærekraftig UVF - fra drenerte byer til grønne, levende, klimatilpassede og vannbevisste byer.

3.5. UiB- og høgskolefinansierte prosjekter

3.5.1 Agent-basert modellering for forvaltning av oppdrett i åpne marine miljø

I et samarbeid med Høgskolen i Ålesund, nå NTNU, ble GSD tildelt en stipendiatstilling innen den marine sektor. Prosjektet har ledet fram til en doktoravhandling basert på et modellbasert studium av betingelsene for et bærekraftig havbruk i et norsk fjordmiljø av patogener. PhD kandidat Alalyat Saleh Abdel-Afou, Palestina, har vært tilsatt i dette prosjektet og har nylig avsluttet sitt avhandlingsarbeid.

3.5.2 Analyse av integrerte evalueringsmodeller (integrated assessment models (IAMs)) i lys av klima-endringer

Som ledd i satsingen på klima-forskning ved UiB, ble GSD tildelt en stipendiatstilling for å vurdere betydningen av feedback knyttet til naturlig kapital i klassiske «Integrated Assessment Models». I prosjektet «Feedback effects of natural capital in the integrated assessment of global warming» blir det gjort en vurdering av fire forhold som ikke er representert på en tjenlig måte i slike modeller; - naturlig kapital uten innvirkning på klimaet, økonomiske konsekvenser ved klimatisk ødeleggelse av naturlig kapital, endret teknologisk utvikling; og endogen strukturell endring i etterspørsel. Prosjektet har bidradd til å identifisere årsaker til den uenighet som foreligger omkring klimatiltak og gir forslag til forbedring av klassiske «Integrated Assessment Models». PhD kandidat Stian Hacket, Norge, har vært tilsatt i dette prosjektet og har nylig avsluttet sitt avhandlingsarbeid.

3.5.3 Teori, metoder, teknikker og verktøy for utvikling og evaluering av modell-baserte interaktive læremiljø

I et samarbeidsprosjekt med programvareleverandøren isee Systems, USA, (se 3.6.1) tar vi i bruk teori, metoder, teknikker og verktøy for utvikling og evaluering av en rekke web-baserte interaktive læremiljø. I dette prosjektet nyttes programvaren Stella Architect til en sømløs utforming av underliggende simuleringsmodeller og web-baserte læremiljø og til innsamling av brukerinformasjon som forteller om de lærendes bruk og nytte av læremiljøet. Slik informasjon danner grunnlag for læringsforskning: Den forteller oss hvilke problemer de lærende har i møtet med komplekse, dynamiske problem og hvordan slike miljøer kan utformes på en måte som fremmer god læring. En PhD kvote-stipendiat, Aklilu Tadesse, Etiopia, arbeider i dette prosjektet sammen med en rekke masterstudenter.

3.5.4 Malaria, - en modell-basert analyse av den epidemiologiske utvikling i Kenya og Etiopia

Som ledd i satsingen på klima-forskning ved UiB, ble GSD tildelt en stipendiatstilling å gjennomføre en modell-basert analyse av utbredelsen av malaria i Kenya og Etiopia på regionalt og nasjonalt nivå. Analysen er basert på en eksplisitt representasjon av livssyklusen til malaria-myggen og - parasitten. Studien gjennomføres i samarbeid med Millennium Institute (https://www.millennium-institute.org), Washington, DC.

Et av de viktigste funnene i denne studien er at forholdet mellom malaria-prevalensen i hhv. mygg og mennesker er lik en konstant som avhenger av entomologiske faktorer og det gjennomsnittlige antall bitt per mygg. Det er mange konklusjoner som følger av et slikt resultat, - herunder at en høy-prevalens blant mennesker er forenlig med en lav prevalens blant mygg. Under slike forhold er transmisjonsraten betinget i mindre grad av mygg-tettheten enn av malaria-prevalensen blant mennesker. Derfor bør smitte-reduserende tiltak innrettes mot en reduksjon av smitte fra mennesker til mygg. PhD kandidat Santiago MovillaBlanco, Spania, er tilsatt i dette prosjektet.

3.5.5 Modell-basert evaluering av grønn-blå infrastrukturtiltak i urbane miljø

GSD samarbeider med Center for Climate and Energy Transition (CET) ved UiB i et prosjekt der grønn-blå infrastrukturløsninger vurderes som ledd i det å redusere klima-utslipp i urbane miljø og det å gjøre urbane strøk mer motstands- og leve-dyktige i møte med klima-endringer. Til dette kreves en systemtilnærming som gir innsikt i urban kompleksitet; - samspillet mellom mennesker, naturlig miljø og bygget miljø, og skaper et grunnlag for utvikling av en bære-kraftig politikk for utvikling av urbane sentre. I prosjektet gjennomføres en modell-basert scenario-analyse der gjennomførbarheten og effekten av en rekke grønn-blå tiltak blir vurdert. I dette prosjektet finansierer CET en PhD kandidat, Brooke Wilkerson, USA.

3.5.6 Dyphavsressurser – bærekraftig innovasjon, eksplorasjon, produksjon

I et samarbeide med Havlaboratoriet, Mat Nat fakultetet, ble GSD tildelt en tverrfakultær stipendiatstilling innen den marine sektor med fokus på en bærekraftig utnyttelse av dyphavsressurser.

Formålet med dette prosjektet er å studere det dynamiske samspillet mellom innovasjon, eksplorasjon og produksjon med tanke på å utnytte ressurser på store havdyp.

For først å peke på det innovative aspektet ved denne forskningen, vil en bl.a. se på basalt-lagene langs Atlanterhavsryggen som et reservoar for kjemisk binding og lagring av CO_2. Dette vil kunne gjøre gass-produksjonen i Nordsjøen og de nordlige havområder bærekraftig også i et miljø-perspektiv. Lagringsplass for CO_2 er altså i seg selv en dyphavsressurs.

For dernest å illustrere dynamikken i utnyttelse av dyphavsressurser generelt, kan vi slå fast at investeringer må komme som et resultat av inntektene fra ressursproduksjon og vil være betinget av den foreliggende markedstilstanden, det etablerte skatteregime etc. Investeringer vil bli splittet mellom utnyttelse av foreliggende teknologi og utvikling av ny teknologi, - det være seg eksplorasjons- eller produksjonsteknologi.

Foreliggende produksjonsteknologi utnyttes i den grad ressursen er identifisert og er økonomisk drivverdig. Om den ikke lenger er det, står vi overfor to valg. Vi kan utvikle ny produksjonsteknologi gjennom innovasjon for å kunne utnytte mer effektivt eller i større omfang den ressursen som allerede er identifisert. Alternativt kan vi investere i ytterligere eksplorasjon gjennom utnyttelse av foreliggende teknologi med sikte på å gjøre nye funn. Eller vi kan gjøre begge deler. Om den foreliggende eksplorasjonsteknologien ikke lar oss finne mer, kan vi velge å videreutvikle også den gjennom investeringer i innovasjon.

Som vi opplever i dagens olje- og gass-industri, er fysiske ressurser ikke fornybare. Over tid oppstår det derfor et produktivitetstap, som vi vil søke å kompensere med ytterligere investeringer i innovativ teknologi-utvikling. Biologiske ressurser er gjerne fornybare, forutsatt at de forvaltes fornuftig og høstes på en bærekraftig måte. Dette innebærer at produksjonsteknologien er en forvaltningsteknologi. Termiske ressurser vil, i praksis, være uendelige men stille krav til forholdvis store investeringer i teknologi med forholdsvis lang levetid.

I dette prosjektet vil vi studere det komplekse samspillet mellom;

- dyphavsressursen, enten den er fornybar eller ei;
- anvendelsen av foreliggende teknologi i hhv. eksplorasjon og produksjon;
- innovasjon innen eksplorasjons- og produksjonsteknologi; og
- ressursmarkedet.

Dette er et samspill som i stor grad er preget av ulineære feedback-prosesser, av store forsinkelser og av betydelig usikkerhet. Vi foreslår derfor å nytte systemdynamikk, altså data-maskinell modellering og simulering i studiet av komplekse, dynamiske systemer, som metode på dette området.

Innen dette prosjektet vil vi gjennomføre et modell-basert studium av de naturgitte, teknologiske, forsknings- og utviklingsmessige og økonomiske forutsetningene må ligge til grunn for en fremtidig samfunnsutvikling i Norge basert på dyphavsressurser. En slik modell vil danne utgangspunkt for utvikling av en strategi, område-spesifikke policies og beslutningstaking innen innovasjonsbasert utnyttelse av dyphavsressurser på nasjonalt, regionalt og virksomhetsnivå. PhD kandidat Lars Kristian Lunde Trellevik, Norge, er nylig tilsatt i dette prosjektet.

3.5.7 Modell-basert analyse av helse, vekst og overlevelse i marine miljø

I et samarbeid med Gruppen for fiskeri-økologi og akvakultur, Mat Nat fakultetet, ble GSD tildelt en fakultetsfinansiering for videreføring av en modell-basert analyse av sammenhengen mellom fiskehelse og et bærekraftig havbruk. Prosjektet tar sikte på å avdekke sammenhengen mellom en rekke faktorer i fiske-oppdrett som påvirker fiske-helsen og, derigjennom, vekst og overlevelse i oppdrett. Analysen vil utnytte systemdynamisk modellering, simulering og analyse, og er basert på en patentert metode for analyse av et omfattende biologisk materiale som samles inn fra en rekke oppdrettsanlegg langs Vestlandskysten.

3.6 Virksomhetsfinansierte prosjekter

3.6.1 Teori, metoder, teknikker og verktøy for modellering, analyse og optimalisering av komplekse dynamiske systemer og for formidling av systeminnsikt.

GSD samarbeider på dette området med isee Systems, USA, produsenten av programvaren Stella Architect. Dette er et 12-årig samarbeid som har ledet til at mange av de metoder og teknikker som er utviklet i ved SDG, er implementert i denne verktøykassen. Dette gjelder verktøy for;
- systemanalyse med det siktemål å identifisere dominante strukturelle elementer i systemer og endogene endringer i slik dominans;
- optimering med det siktemål å validere modeller (parameter-estimering etc.) og identifisere prinsipper for god ledelse av systemer.

P.t. gjennomføres et prosjekt der vi utvikler og kombinerer en rekke avanserte analyse- og optimeringsverktøy i strukturering av og mønstergjenkjenning i store datamengder. Dette arbeidet ventes å lede fram til identifisering av kausale mekanismer som gjør at DNA kommer til uttrykk i produksjon av proteiner og spesialisert celle-dannelse i utviklingen av organismer. Fremst i dette arbeidet ved isee Systems står en av våre doktorgradskandidater, William Schoenberg, USA, som finansieres av isee Systems.

3.6.2 Bærekraftig utnyttelse av landområder gjennom planlegging basert på en syntese av systemdynamikk og geografiske informasjonssystemer

GSD samarbeider med KnowlEdge srl (https://www.ke-srl.com), etablert og ledet av dr. Andrea Bassi, en av våre tidligere Ph D kandidater. KnowlEdge srl tilbyr modell-baserte studier av bærekraft til land og regioner verden over. Eksempelvis KnowlEdge srl bak den systemdynamiske modellen som ble lagt til grunn for UNEP sin Green Economy Report 2011 (https://naturalsciences.ch/service/publications/76477-unep-green-economy-report-2011).

Prosjektet understøtter regional arealplanlegging i fire dimensjoner gjennom å kombinere tids-dimensjonen i systemdynamisk modellering med de romlige tre dimensjonene, representert i Geografiske Informasjons Systemer (GIS). Formålet med introduksjonen av tids-dimensjonen i dette prosjektet, er å styrke vektleggingen av langsiktig ***bærekraft i arealplanlegging***. Fremst i dette arbeidet står en av våre doktorgradskandidater, Georg Pallaske, Tyskland, finansiert av KnowlEdge srl.

3.7 Eksternt, offentlig finansierte prosjekter

3.7.1 Latvia-finansierte prosjekter

GSD har, i en årrekke, samarbeidet med Riga Technical University omkring nasjonale omstillingstiltak i Latvia, - hovedsakelig energi-omstilling og utviklingen av en bio-økonomi. Prosjektene i dette samarbeidet har vært finansiert gjennom den norske del av EAA-programmet.

Som et resultat av dette samarbeidet, finansierer nå den Latviske stat et 3-årig prosjekt for modell-basert analyse av de omstillingstiltak Latvia må gjennomføre for å nå bærekraftmålene landet har forpliktete seg til overfor EU. GSD er representert i styringsgruppen for dette prosjektet og bidrar aktivt i planlegging og gjennomføring.

3.7.2 Italia-finansierte prosjekter

GSD samarbeider med Universitetet i Palermo om en ***dobbelt doktorgrad*** i systemdynamikk og modell-basert ledelse i den offentlige sektor. Studiene stipendfinansieres av den italienske stat. Så langt har to kandidater forsvart sine avhandlinger innen rammen av dette programmet, - begge innen bærekraft-paradigmet (med fokus på sikre hhv. et robust landbruk i Guatemala i lys av klimaendringer og en robust behandling av mental helse i amerikanske fengsler). Tre studier, finansiert på samme måte, er nå i gang:

3.7.2.1 Betingelser for bærekraftig kommersialisering av teknologier for karbon-fangst, lagring (CCS) og utnyttelse i olje-produksjon (EOR)

I dette forskningsprosjektet undersøkes det dynamiske bærekraft-aspektet ved kommersialiseringen av teknologier for fangst, lagring og utnyttelse av karbon (CO_2) i oljeproduksjon i USA. I dag er kostnadene ved CCS for høye til å bli kompensert av innsparing av utslippsavgifter. Det innebærer at den private sektoren ikke finner det lønnsomt å investere i CCS. Det blir hevdet at bruken av CO_2 i forsterket oljeproduksjon (Enhanced Oil Recovery, EOR) er en

potensiell kilde til inntekter fra CCS som kan kompensere ytterligere for CCS kostnader, - gitt at det foreligger en stigende læringskurve og muligheter for stordriftsfordeler. Studien integrerer operasjonell kunnskap om CCS og EOR i en tekno-økonomisk modell som kopler de to industriområdene. Modellen nyttes til å studere utviklingstrender for utbredelse av CCS under ulike scenarier vedr. olje-pris, klimapolitikk (herunder avgifter) og teknologi-utvikling og -bruk (herunder kostnadsantakelser). Utviklingstrendene gir innsikt i effekten av en avgiftspolitikk på et CO_2 marked basert på CCS/EOR. Ph D kandidat Edoard Romanenko, Russland, er stipendiat i dette prosjektet.

3.7.2.2 Finansielle og fysiske betingelser for et bærekraftig råoljemarked

I dette prosjektet gjennomføres en modell-basert studie av sammenhengen mellom olje-produksjonspolitikken i Venezuela og OPEC. I prosjektet blir investeringsfunksjoner og -beslutninger utenfor OPEC identifisert, - under antakelser om OPEC´s strategi. Dessuten identifiserer studien en optimal produksjonspolitikk for OPEC, - gitt usikkerheten som er knyttet til den produksjons- og konsum-teknologiske utvikling og foreliggende ressurs-begrensinger. Ph D kandidat Omar Chique, Venezuela, er stipendiat i dette prosjektet.

3.7.2.3 Betingelser for et bærekraftig system for ivaretakelse av folkehelsen i Lombardia (Italia) med fokus på kroniske sykdommer

I dette prosjektet gjennomføres en modell-basert studie av en ny politikk for overvåking og behandling av kronisk syke i Lombardia. Siktemålet med denne politikken er å identifisere mennesker i et tidlig stadium av kronisk sykdom, iverksette behandling på dette stadium og, ikke minst, tilby disse pasientene en tett oppfølging med det siktemål å forsinke deres sykdomsprogresjon, bedre deres livskvalitet og forlenge deres levetid. I prosjektet gjøres betingelsene for å nå dette siktemålet på en bærekraftig måte til gjenstand for et inngående studium. Ph D kandidat Olga Tolmachova, Ukaraina, er stipendiat i dette prosjektet.

3.7.3 Sveits-finansierte prosjekter

3.7.3.1 Model-basert verdikjede-analyse av Industry 4.0 prosjekter innen bærekraftige energi-transformasjonsprosesser.

GSD samarbeider med Bern University of Applied Sciences (BFH), Sveits, i et prosjekt vedrørende modell-basert analyse av verdi-kjedene i energiforsyningsselskaper som aspirerer mot en bærekraftig Industry 4.0 standard (https://en.wikipedia.org/wiki/Industry_4.0), - og det i et marked som gjennomgår betydelige omstillinger. BFH finansierer en av våre doktorgradskandidater, Dovood Qorbani, Iran, i dette prosjektet.

3.7.3.2 Model-basert analyse og ledelse av omstillingsprosesser i bygningsindustrien

GSD har et samarbeid med University of Applied Sciences, St Gallen (FHS St. Gallen), Sveits, i et prosjekt omkring omstillingsledelse i bygningsindustrien med det siktemål å utvikle et sam-

virke mellom offentlig politikk og bærekraftige bedriftsmodeller. Omstillingsledelse har de senere årene fremstått som en refleksiv ledelsesform som er basert på medvirkning fra interessenters side (stakeholder participation). Slik ledelse anvendes ofte i regionale utviklingsprosesser som gjennomføres inne rammen av et bærekraftsperspektiv der marko-dynamikk på et system-nivå sees i lys av mikro-dynamikken som genereres på virksomhets-nivå. Konkret studerer man hvordan en politikk for offentlige innkjøp, avfallshåndtering, CO2 regulering og arealplanlegging innvirker på utviklingen av alternative bedriftsmodeller i Sveits. Til dette nyttes en simuleringsmodell som blir utviklet, validert, analysert og anvendt av et utvalg av material-intensive bygningsfirma, NGO´er, politiske organisasjoner og industri-foreninger. Systemdynamikk nyttes derved som en strukturerende og integrerende metode i prosjektet og i gjennomføringen av scenario-analyser med det formål å utvikle en strategi som leder en ressurskrevende industri inn i en bærekraftig utvikling. Prosjektet bidrar både med et kort- og et langsiktig omstillingsperspektiv, understøtter vurderingen av omstillingstiltak og stimulerer til en sosial læringsprosess blant deltakerne. Det sveitsiske forskningsrådet (#73 – Sustainable Economy) finansierer vår Ph D kandidat. Daniel Kliem, Sveits, som deltar i dette prosjektet.

3.7.4 Pakistan-finansierte prosjekter: Analyse av betingelsene for private bedrifters finansielle bærekraft

GSD har et samarbeid med The Woman University, Multan, Pakistan, og Oslo MET innen finansiell analyse. I dette prosjektet finansieres vår doktorgradskandidat Aima Khan, Pakistan, gjennom et statlig stipend-program, for å studere fundamentale prinsipper for en bærekraftig investering i, finansiering av og utbytte-fordeling blant eierne av private bedrifter, - basert på mikro-økonomisk teori. Dette er et modell-basert forskningsarbeid som har som formål å nå fram til prinsipper for utvikling av bedrifts-finansiell strategi og taktikk med det siktemål å maksimere en bedrifts verdi over tid.

3.7.5 Malaysia-finansierte prosjekter: Matvaresikkerhet i Malaysia

GSD har et samarbeid med Universiti Putra Malaysia omkring en modell-basert studie av matvaresikkerhet. Malaysia står overfor betydelige utfordringer når det gjelder å skaffe mat til en stadig voksende og krevende befolkning. Samtidig må Malaysia reetablere en utarmet base av ressurser for matvareproduksjon. Dette innebærer et behov for å intensivere matvareproduksjonen på en bærekraftig måte. Et eksempel på dette er å kombinere risproduksjon med fiskeoppdrett (i rismarkene), - der rismarkene gir gode levevilkår for fisk og der fisken bidrar til å gjødsle rismarkene.

Sammen med Universiti Putra Malaysia, finanansierer det malaysiske undervisningsdepartementet og Southeast Asian Regional Center for Graduate Study and Research in Agriculture en av våre doktorgradskandidater, Emmy Farah Binti Alias, Malaysia, sitt studium av prosesser som driver utbredelsen av slike bærekraftige intensifiseringstiltak, - herunder betingelsene for at slike tiltak skal virke økonomisk og sosialt tilfredsstillende for bøndene. Modellen som er under utvikling i dette prosjektet, skal gjøre det mulig å vurdere betingelsene for anvendelse og effekten av slike tiltak, - herunder den optimale plasseringen av slike tiltak langs en tidslinje.

4. Undervisning og internasjonalt undervisningssamarbeid

4. 1 Bachelorprogram

Ved fakultetet fikk vi, i forrige dekan-periode, administrativt godkjent våre planer om å etablere en tverrfaglig bachelor-grad med systemdynamikk som en «major». Men fakultetsledelsen har ikke tatt initiativ til å realisere disse planene til tross for at rektor var villig til å vurdere en bro-finansiering for et slikt studium. I den forbindelse sendte Prof. John D. Sterman, MIT, en uttalelse om betydningen av et slikt initiativ (se vedlegg 6).

Som beskrevet i avsnitt 5.4, er det nå tatt initiativ til et strategisk ERASMUS + program med det siktemål å etablere en tverrfaglig MOOCs-basert bachelor-utdanning i Europa med vekt på SDGs langs de samme retningslinjene vi foreslo lokalt.

4. 2 Masterprogram

Med sitt master og Ph D program, ansees GSD som et internasjonalt senter for utdanning innen systemdynamikk. GSD tilbyr to masterprogram;
- ett internasjonalt M. Phil program, Bergensprogrammet, opprettet i 1995 etter initiativ fra Universitetsdirektøren;
- ett europeisk flergradsprogram, European Masters programme in System Dynamics. (EMSD).

4.2.1 Bergensprogrammet (https://www.uib.no/fg/dynamikk#)

Programmet i Bergen er engelsk-språklig og har, i løpet av 24 år, utdannet om lag 400 masterstudenter, - i all hovedsak utenlandsstudenter rekruttert med bachelorgrad i samfunnsfag, inkl. bedriftsledelse, og naturfag, inkl. ingeniørfag. Sett i lys av at vi ikke har et rekrutterende Bachelor-program i bunn, har søknaden til studiet vært svært tilfredsstillende.

P.t. er programmet organisert i 3 semester med kursarbeid (9 kurs á 10 studiepoeng) og en masteroppgave på ett semester. Programmet i Bergen er innrettet mot systemdynamikk generelt; modellering, simulering, analyse, og formidling av kunnskap om komplekse, dynamiske systemer i form av interaktive læremiljø.

I all hovedsak er temaene for kursene knyttet til anvendelser av systemdynamikk i analyse av ***bærekraft-målene***; forvaltning av naturressurser i bred forstand, matvareproduksjon og -sikkerhet, helse, utdanning, miljøvern, næringsutvikling, nasjonal utviklingsplanlegging, samt modellbasert utvikling, implementering og evaluering av strategier, virkemidler og beslutninger, ekspert- og interessent-medvirkning, og formidling.

Så langt tilbys ett av våre kurs som en MOOC. Ettersom vi arbeider med interaktive læremiljøer både som virkemiddel og som tema i undervisningen, - er vi på full vei mot å utvikle en kursportefølj som i stor grad vil være digitalisert. (Mer om dette i avsnitt 5.4).

4.2.2 European Masters in System Dynamics EMSD (http://europeansystemdynamics.eu)

EMSD ble opprettet 2009, og tilbys i samarbeid med Radboud University, Nederland, NOVA University, Lisboa, Portugal, og University of Palermo, Italia. Dette programmet har, inntil nylig, vært støttet av EU i form av et ERASMUS MUNDUS program og har utdannet ca 200 studenter. Iflg. en tracer-studie gjennomført nylig er 40% av studentene fortsatt i akademiske stillinger eller ansatt i forskningsinstitusjoner. Det er grunn til å tro at dette også gjelder studentene som utdannes i Bergensprogrammet. Dette gjenspeiler seg også i rekrutteringen av eksternt finansierte kandidater til vårt eget Ph D program.

I dette programmet gjennomfører alle studentene sitt første semester og 30% av dem sitt fjerde semester i Bergen. I andre semester kan studentene spesialisere seg i anvendelse av systemdynamikk i offentlig forvaltning (Palermo) eller bærekraft-studier (Lisboa). I tredje semester forbereder studentene sine oppgave-arbeider og de trenes i Group model building og Community-based system dynamics (Nijmegen), altså det å modellere i felt. I andre og tredje semester står altså praksis-arbeid sentralt. Fjerde semester bruker studentene på masteroppgavene sine ved et lærested de finner interessant, - et partneruniversitet eller et universitet utenfor Europa som er knyttet til ESMD programmet.

4. 3 Ph D program

Helt sentralt i Gruppen for systemdynamikk sitt utdanningstilbud står Ph programmet som har bred internasjonal oppslutning, - hovedsakelig fra kandidater med ekstern finansiering. Programmet er rettet mot forskning innen systemdynamisk teori, metode, teknikker og verktøy (programvareutvikling) og modell-basert analyse av problemstillinger som faller innen bærekraft-begrepet.

GSD er en av samarbeidspartnerne i et nytt kurstilbud på Ph D nivå ved UiB: Ph D for innovation: Interdsciplinary problems solving and creativity (http://phdforinnovation.com). Utgangspunktet er behovet for kreative løsninger på de bærekraftutfordringer som Agenda 2030 representerer i form av SDGs og deres samvirke.

Tabellene over 20 utdannede kandidater og 16 kandidater under utdanning taler for seg selv, både mhp; - yrkesvalg (for dem som har disputert); - bærekraft-orientering i valg av forskningstema og yrke; - internasjonal bredde; og - variasjon i kilde til (ekstern) finansiering.

For tiden arbeider alle som er uteksaminert med tema som omfattes av SDGs, - herunder miljø-orientert nasjonal planlegging og utviklingsarbeid, infrastruktur-analyse, krisehåndtering i lys av klima-endringer, nasjonal- og delingsøkonomi, og helse og utdanning i klima-utsatte områder av verden.

20 Ph D kandidater utdannet 2002 - 2018				
Navn (kjønn, disp. år)	**Tema**	**Finansiering**	**Nasjon**	**Yrke**
M. M. Saleh (M 2002)	Systemdynamisk analyse metode	Kvote-stipend	Egypt	**Professor** Kairo University, Egypt (https://scholar.cu.edu.eg/?q=saleh/)
A. Sawicka (F, 2004)	Informasjons-sikkerhet	Kristiansand kommune	Polen	Nasjonal Kommunikasjonsmyndighet (https://www.nkom.no)
M. Milrad (M, 2006)	Modell-basert media-teknologi	Svensk statsstipend	Brazil	**Professor** Linnaeus Universitetet , SE (https://lnu.se/en/staff/marcelo.milrad)
S. Arango (M, 2006)	Eksperimentell økonomi: Analyse av olje-markedet	Kvote-stipend	Colom-bia	**Professor** National University, Medellin **Senior Research Fellow** EfD Colombia (https://efdinitiative.org/about-efd/people/arango-aramburo-santiago)
D. Wheat (M, 2007)	Modell-basert økonomiutdanning	Wheat Resources	USA	**Professor:** a. UiB (emeritus), https://www.uib.no/en/persons/David.Wheat b. ISM, Lithauen https://www.ism.lt/node/3484 c. NaUKMA, Ukraina. http://finance.ukma.edu.ua/en/vikladachi/2011-05-07-23-00-03/vikladachi/vit-aira-devid
J. Wiik (M, 2007)	Nasjonal Informasjons-sikkerhet	Høgskole-finansiert, Agder	Norge	**Partner** Deloitte https://www2.deloitte.com
A. Qureshi (M, 2008)	National utviklings-planlegging med vekt på National Accounting Matrix	Kvote-stipend	Paki-stan	**Asc. Professor** Oslo MET https://www.oslomet.no/om/ansatt/muhaqu/
S. Kharib (M, 2008)	Landskapsplanl.. Gjennom koplede GIS og SD modeller	Kvote-stipend	Egypt	**Senior Urban Designer** Dar Al Riyad Group, Saudi Arabia http://www.daralriyadh.com/en/
M. Pedercini (M,2009)	Modellbasert utviklings-planlegging	Millennium Institute	Italia	**Vice President & Chief Operating Officer** Millennium Institute: NGO innen offentlig bærekraftplanlegging: https://www.millennium-institute.org

A. Bassi (M. 2009)	Modellbasert analyse av energiomstilling på ulike aggregeringsnivåer	Millennium Institute	Italia	**CEO** KnowlEdge Srl : Rådgiver innen offentlig bærekraftsplanlegging: https://www.ke-srl.com
J. P. Ansah (M, 2009)	Gjeldsakkumulering og fattigdomsfellen i Afrika	Kvote-stipend.	Ghana	**Assistant Professor & Research Fellow** DUKE - National University of Singapore (NUS) Medial School, Health Services and Systems Research http://rc4.nus.edu.sg/fellows/john-pastor-ansah/
J. Radianti (F, 2010)	Det svarte market for datasikkerhet	Høgskole-stipend, Agder	Indo-nesia	**Forskningsleder** **CIEMlab** Senter for Integrert Krisehåndtering Universitetet i Agder https://home.uia.no/jaziarr/index/
Y. Qian (F, 2010)	Datasikkerhets-utfordringer ved automatisering av norsk sokkel	Høgskole-finansiert, Agder	Kina	**Asc. Professor** Shanghai University http://www.shu.edu.cn
M. Saldariaga (F, 2011)	Pedagogisk anvendelse av systemdynamikk I naturfag	Kvote-stipend	Colom-bia	**Ass Professor & Department Chair** Departm. of Mathematics and Nat Sci., American University of Irak https://auis.edu.krd/maria-saldarriaga-assistant-professor-mathematics-and-natural-sciences-department-chair
S. Derwich (M, 2012)	Patentrettigheter i matvareproduksjon; Forsterket mais i det sørlige Afrika	CGIAR	Tysk-land	**Forsker** Business Application Research Centre www.barc-research.com
J. Hartwig (M, 2017)	Målkonflikter mellom patentretten, vekst og konjunktur.	Frauenhofer Universitets-stipend	Tysk-land	**Senior Economist** MFive GmbH Mobility, Futures, Innovation, Economics https://www.m-five.de https://www.linkedin.com/in/johannes-hartwig-942078b1/?locale=zh_CN
A. Gerber (M, 2017)	Agriculture-based food security in South Sahara Africa: Central policies and local adaptation.	NFR stipend	Sveits	**Post Doctoral Fellow** Department of informatics Sustainability Research Group, University of Zürich https://www.ifi.uzh.ch/en/isr/people/people/gerber.html

D. Lara Arango (M, 2018)	Eksperimentell økonomi: El. kraftmarkedet og kraftoverføring	Kvote-stipend	Colom-bia	**Seniorkonsulent** Business Intelligence Webstep https://www.webstep.no/ansatt/david-lara-arango/
H. Hurrera (M. 2018)	Bærekraft i sosio-økologiske systemer under klima-skifte	Palermo universitets-stipend	Guate-mala	**Specialist Consultant** a. Department for Business, Energy & Industrial Strategy https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy b. UNEP https://www.unenvironment.org
Y. J. Lee (F. 2018)	Mental sykdom fanger I California; - behandling og bærekraft.	Palermo Universitets-stipend	Malay-sia	**Vurderes for Forskerstilling** Folkehelse I Kina Universitetet i Agder

16 Ph D kandidater under utdanning			
Navn **(kjønn, est. disp. år)**	**Nasjonalitet**	**Finansiering**	**Tema**
S. Hackett (M, 2019)	Norge	Universitets-stipend	Analyse av integrerte evalueringsmodeller (integrated assessment models (IAMs)) i lys av klima-endringer.
A.S. Abdel-Afou (M.2019)	Palestina	Høgskole-stipend, Ålesund	Agent-basert modellering for forvaltning av oppdrett i åpne marine miljø
S.M.Blanco (M, 2019)	Spania	Universitets-stipend	Malaria, - en modell-basert analyse av den epidemiologiske utvikling i Kenya og Etiopia.
A. Tadesse (M, 2019)	Etiopia	Kvote-stipend	Teori, metoder, teknikker og verktøy for utvikling og evaluering av modell-baserte interaktive læremiljø
E. Romanenko (M,2019)	Russland	Palermo Universitets-stipend	Betingelser for bærekraftig kommersialisering av teknologier for karbon-fangst, lagring (CCS) og utnyttelse i olje-produksjon (EOR).
O. Chique (M, 2020)	Venezuela	Palermo Universitets-stipend	Finansielle og fysiske betingelser for et bærekraftig råoljemarked.

O. Tolmachova (F, 2020)	Ukraina	Palermo Universitets-stipend	Betingelser for et bærekraftig system for ivaretakelse av folkehelsen i Lombardia (Italia) med fokus på kroniske sykdommer.
A. Khan (F, 2020)	Pakistan	Pakistansk stipend	Analyse av betingelsene for private bedrifters finansielle bærekraft.
E. F.B. Alias (F, 2020)	Malaysia	Malaysisk stipend	Matvaresikkerhet i Malaysia: Co-farming av ris og fisk.
W. Schoenberg (M, 2020)	USA	Isee Systems	Teori, metoder, teknikker og verktøy for modellering, analyse og optimalisering av komplekse dynamiske systemer og for formidling av systeminnsikt.
G. Pallaske (M, 2021)	Tyskland	KnowlEdge Srl.	Bærekraftig utnyttelse av landområder gjennom bedre planlegging basert på en syntese av systemdynamikk og geografiske informasjonssystemer.
D. Qorbani (M, 2021)	Iran	Sveitsisk Høgskole-stipend Bern	Model-basert verdikjede-analyse av Industry 4.0 prosjekter innen bærekraftige energi-transformasjonsprosesser.
A. Aguilar (F, 2021)	Colombia	CoCreate (Horizon 2020)	Co-Create (Horizon 2020): En modell-basert studie av overvekt og holdninger til overvekt blant ungdom, matvareprodusenter og myndigheter i Europa.
D. Klim (M, 2021)	Sveits	Nat Research Progr. 73; Sustainable Economy	Model-basert analyse og ledelse av omstillingsprosesser i bygningsindustrien.
B. Wilkerson (F, 2021)	USA	Universitets-stipend	Modell-basert evaluering av grønn-blå infrastrukturtiltak i urbane miljø.
L-K. L. Trellevik (M, 2021)	Norge	Universitets-stipend	Dyphavsressurser – bærekraftig innovasjon, eksplorasjon, produksjon.

4.4 Øvrig internasjonalt undervisningssamarbeid

I Bergensprogrammet (det lokale masterprogrammet) samarbeider GSD med en rekke partnere som bidrar til å styrke undervisningen. På den måten blir undervisningen aktuell, relevant og inspirerende. Videre bringer disse partnerne gjestestudenter med domene-kompetanse til

Bergen for spesialisering. Samspillet mellom regulære studenter og gjestestudenter skaper en gjensidig berikelse av miljøet.

4.4.1 Millennium Institute (MI) (NGO), USA

I 2003 inngikk SDG en samarbeidsavtale om forskning og utdanning med Millennium Institute (MI) (NGO), Washington D.C. (https://www.millennium-institute.org). MI gjennomfører modell-baserte analyser med henblikk på SDGs for en rekke nasjonale myndigheter verden over. I kurset GEO-SD 321, Modell-basert sosio-økonomisk planlegging, gir lederen ved for forskning og utvikling ved MI, dr. Matteo Pedercini (utdannet ved GSD), en fire ukers intensiv innføring i bruk av Threshold 21 (T21), - rammemodellen som anvendes som utgangspunkt for MIs globale arbeid. I den forbindelse bringer MI opp til 15 gjestestudenter fra ulike nasjonale myndigheter til kurset for spesialisering her i Bergen.

4.4.2 isee Systems, USA

isee Systems, USA (https://www.iseesystems.com) har implementert GSD sine prinsipper for utvikling og bruk av web-baserte interaktive læremiljø (Interactive Learning Environments - ILEs) i programvaren Stella Architect. Dette tillater oss å realisere en sømløs arbeidsprosess sfra modellering, simulering og analyse til web-basert formidling i form av ILEs. Det er denne teknologien vi nå gjør bruk av både i klasserom, i oppgaveløsning (case studies) og i MOOCs som vi tilbyr ved UiB så vel som på nettet.

Isee Systems´ programvareutvikler på dette feltet, William Schoenberg (utdannet ved SGD), tilbyr hvert år en 3 ukers intensiv innføring i utvikling av interaktive læremiljø som ledd i kurset GEO-SD 309, Model-based Interactive Learning Environments. Dette følges opp med prosjektoppgaver som studentene presenterer ved slutten av semesteret, - da gjerne i form av én- eller flerbruker-spill og ofte av så stor pedagogisk verdi at de inkorporeres i vår undervisning.

4.4.3 DIKU: Ukraina

Siden 2012 har Gruppen for systedynamikk v/ professor David Wheat (nå emeritus), gjennom flere prosjekter finansiert av SIU/DIKU, utviklet et nært samarbeid med National University of Kyiv-Mohyla Academy (NaUKMA) og Ivan Franko University of Lviv i Ukraina. Samarbeidet er sentrert omkring modell-basert undervisning i økonomi. Siktemålet har vært å styrke den langsiktige økonomiske bærekraften i Ukraina. Nasjonalbanken i Ukraina deltar i samarbeidet, og med sin geopolitiske betydning er prosjektet besøkt ved to anledninger av hhv. *statsminister Solberg* og *utenriksminister Eriksen Søreide*. Mellom UiB og NaUKMA er det nylig inngått en avtale om felles doktorgradsutdanning (dobbeltgrad) i systemdynamikk. Prosjektet er nå forlenget med finansiering ut 2021.

Resultatene av dette samarbeidet er omfattende:

- Det er etablert ett lavere grads kurs og to høyere grads kurs i økonomisk modellering ved NaUKMA. 8 andre kurs er basert på modell-baserte pedagogiske prinsipper utviklet ved GSD.

- Mer enn 100 BA, MA og Ph D studenter og stabsmedlemmer har gjennomført minst ett semesters utdanning i Bergen, etterfulgt av videre opplæring i Ukraina.

- En makro-økonomisk simuleringsmodell for Ukraina er i stadig videreutvikling som ledd i dette samarbeidet.

- NaUKMA tilbyr ett MOOCs-basert kurs innen fagområdet.

- 3 doktorgrader er blitt avlagt basert på systemdynamiske anvendelser i økonomifaget, - ytterligere 4 arbeider er på gang.

- Systemdynamisk metode har vært i bruk i over 24 ferdigstilte masteroppgaver ved NaUKMA.

- I 2018 ble en forskningskonferanse med tittelen; «System dynamics modeling for public and corporate finance: Background and opportunities» avholdt ved NaUKMA;

- Mer enn 68 vitenskapelige artikler er skrevet som et resultat av dette samarbeidet;

- Representater fra NaUKMA og Lviv har deltatt de 6 siste årene ved International System Dynamics Conference, - og da med i alt 12 presentasjoner;

- 3 monografier er blitt publisert og en rekke workshops er blitt avholdt;

- The Ukrainian System Dynamics and Econometric Center of Excellence er blitt opprettet ved NaUKMA.

4.4.4 DIKU: Nord Dakota, USA

Som ledd i et DIKU-finansiert samarbeid med University of North Dakota (UND), inngikk UiB i 2013 en avtale med UND. Representanter fra UND, under ledelse av hhv. provost og president, har to ganger besøkt UiB og uttrykt ønske om en utvidelse av dette samarbeidet over flere fagfelt, herunder jus og drone-teknologi.

P.t. utveksler UiB studenter med UND med hovedvekt på bruk av modellering og simulering innen folkehelse. Høsten 2018 kommer 3 studenter og en professor til Bergen for utdanning i systemdynamikk. Våren 2019 regner vi med at et tilsvarende antall studenter i Bergensprogrammet vil oppholde seg ved UND.

4.4.5 Climate Interactive (CI) (NGO), USA

Climate Interactive (CI) (https://www.climateinteractive.org) er en NGO som arbeider med det formål å informere verdens befolkning, herunder interessenter og beslutningstakere, om konsekvensene av de resultatene som oppnås i klima-forhandlingene organisert etter initiativ fra FNs medlemsland. Til grunn for dette arbeidet ligger systemdynamiske simuler-ingsmodeller som samsvarer med de modellene som klima-forskere verden over nytter. Climate Interactive har nådd svært langt med sin formidling i mange land verden over, og ønsker nå å samarbeide med GSD for å kunne tilby nett-baserte simulatorer som tillater deltakerne å innta roller som deltakere i klima- forhandlingene. GSD har, med støtte fra fakultetet, utviklet en slik simulator over C-ROADS modellen som CI bruker til dette formålet, - en simulator som vi planlegger å bruke i vår egen undervisning om klima-forhandlinger.

4.4.6 Klient-basert undervisning

I vårt nye kurs, GEO-SD325, Client-Based Modeling, møter studentene reelle internasjonale oppdragsgivere som presenterer sine problemstillinger og uttrykker sine behov for modell-basert assistanse. Studentene utfordres til å gripe fatt i disse problemene i et prosjekt der de utvikler en modell og gjennomfører en analyse med problemløsning for øye. Resultatet presenteres for oppdragsgiveren ved avslutningen av prosjektet. Blant de oppdragsgiverne vi så langt har samarbeidet med, er Flyktningehjelpen i Geneve, WWF og UNEP.

5. Fremtidsperspektiver; forskning og utdanning, samarbeid og søknader

Samtlige av de aktivitetene som er beskrevet så langt, har i seg et fremtidsperspektiv. Dette gjelder spesielt vårt samarbeid med internasjonale organisasjoner omkring SDGs, - ikke minst UNEP. Disse samarbeidsaktivitetene tar vi sikte på å videreføre og styrke. I tillegg bereder vi grunnen for de neste årene. I dette avsnittet beskriver vi noen av våre nye initiativ. Dette er initiativ vi allerede har søkt om ekstern finansiering for.

5.1 Den internasjonale systemdynamikk-konferansen

Vi er blitt tildelt ansvaret for å arrangere den internasjonale systemdynamikk-konferansen sommeren 2020, - en konferanse som normalt trekker 450 deltakere. Temaet for konferansen vil være bærekraft og behovet for omstillingsledelse på en rekke samfunnsområder.

5.2 EMSD

I januar 2019 sendte konsortiet av universiteter som tilbyr det europeiske mastergradsprogrammet i systemdynamikk (EMSD programmet omtalt i avsnitt 4.2.2) (Bergen, Lisboa, Palermo og Nijmegen), en ny søknad til EU om en årlig stipendfinansering av 20 kandidater over Erasmus Mundus programmet, - en videreføring av vårt 10-årige samarbeidet innen dette programmet.

5.3 Marie Curie

Med vår satsing på bærekraftmålene, sendte GSD, i februar 2019, en søknad til EU om finansiering av et Marie Curie prosjekt (se vedlegg 4). GSD gjorde dette som koordinator på vegne av universitetskonsortiet som tilbyr EMSD programmet, samt Riga Technical University. Prosjektet er knyttet til bærekraftsmålene og vil omfatte 15 PH D kandidater som hver vil arbeide på tvers av disse målene sammen med en rekke ikke-akademiske samarbeidspartnere i og utenfor Europa, - herunder UNEP.

5.4 MOOC-basert undervisning og ERASMUS +

GSD har, siden 1995, vært verdensledende i utvikling og bruk av modell-baserte interaktive læremiljø. Ny programvare for modellutvikling, analyse og web-basert formidling av innsikt i komplekse, dynamiske systemer har åpnet opp for utvikling av MOOCs med et banebrytende innhold. Kurset GEO-SD 360, Natural Resource Management, er utviklet og leveres på basis av slik teknologi og er den første poeng-givende MOOC tilbudt globalt av UiB. Vi har en visjon og å forbli ledende innen digital undervisning og utvikler for tiden en rekke kurs-komponenter basert på den nye teknologien.

Som ett slikt tiltak, ser GSD et sterkt behov for en bachelor-utdanning i tverrfaglig analyse av inter-sektorielle problemer. Siktemålet vårt er å utdanne kandidater med et sterkt analytisk fundament for utvikling og evaluering av politikk som strekker seg på tvers av fagfelt og samfunnssektorer. Det er tatt initiativ til et samarbeid mellom flere europeiske universitet i den hensikt å tilby en MOOCs-basert bachelor i systemtenkning for samfunnsendring. Initiativet ledet i april 2019 fram til en søknad om et prosjekt under EU sitt ERAMUS+ strategiske program, koordinert av UiB. Formålet med dette prosjektet er å utvikle 12 MOOCs som tilsammen vil utgjøre kjernen i en slik nett-basert utdanning. Samarbeidspartnerne bak dette initiativet er, igjen, konsortiet av de fire universitet som tilbyr EMSD programmet samt Università della Svizzera Italiana og Riga Technical University.

5.5 Belmont Forum; University of Maryland

Med sitt prosjektforslag «COAST - Coastal Ocean Assessment for Sustainability and Transformation», tok University of Maryland initiativ til et prosjekt med UiB som hovedpartner og med flere akademiske partner-institusjoner i Asia. I april 2019 ble det sendt en søknad om prosjektfinansiering til Belmont Forum som bl.a. omfatter NFR og NSF.

Formålet med prosjektet er å studere tre-fire marine områder i hhv. USA, Filipinene, Japan og India med det for øye å identifisere hva som må til for å sikre at områdene forblir bærekraftige og danner grunnlag for en rettferdig utnyttelse av områdenes marine ressurser, - herunder hvordan så kan skje i lys av globale endringer.

5.6 NFR

I april 2019 sendte UiB, i sin rolle som koordinator, en søknad til NFR om finansiering av et forskningsprosjekt «Horizontal Collaborative Computing for Societal Negotiation Processes». Søknaden ble utformet i samarbeid med et konsortium av følgende institusjoner: ETH Zurich, Chalmers University, University of Social Sciences and Humanities (SWPS), Poland, og Tohoku University, Japan. GSD og Institutt for informasjonsvitenskap deltar som partnere ved UiB som deltar i dette prosjektet. I original-beskrivelsen av prosjektet heter det:

“To reach sustainable development goals, it is crucial to involve stakeholders in Societal Negotiation Processes (SNP) to find solutions grounded in real data, encouraging strong and lasting participation and resulting in more effective policy creation. While available public databases provide multifaceted sources of information such as on affordable energy, agricultural production, clean water or sanitation, they do not sufficiently help SNP stakeholders reach their multiple goals. Collaborative computing tools already exist, but to our knowledge, collaborative access, navigation, modification, and curation of such data leveraging combined use of tabletops and heuristics-based recommendation techniques have yet to be explored. We propose to study what recently developed horizontal collaborative computing and recommendation techniques can offer co-located participants in collaborative policy ("what-if") analysis, such as improved access for the effective navigation, overview, and (re-)use of information from public databases, and reliable suggestions to assist decision-making. This project will study how horizontal computing can enhance collaborative policy

analysis in a variety of European settings for important domains such as sustainable and resilient natural resource management, including energy and farming, as well as climate change in urban planning. While the main impact of this project will be in the area of ICT and collaborative interactive systems, the project will also contribute to the theory of collaboration; especially the role of gaze and behavioral synchronization to achieve shared reality in collaboration. Besides being an HCI project, it will also address long term societal challenges and UN sustainable development goals."

5.7 Akademia-avtalen

I mai 2019 sendte GSD et prosjektforslag med vekt på SDGs innen rammen av Akademia-avtalen. Prosjektet har som siktemål å nytte en kompakt form av «Horizontal Collaborative Computing for Societal Negotiation Processes» (se avsn. 5.6) i en anvendelse som omhandler den rollen «Carbon Capture and Storage» (CCS) kan spille i energiomstillingsprosesser. Dette er tett knyttet opp til prosjektet omtalt i avsn. 3.7.2.1.

5.8 Kappa programmet

GSD samarbeider med Institutt for miljø-studier ved Masaryk University Brno, Tsjekkia, med det siktemål å søke om et langsiktig forskningsprosjekt under Technology Agency of the Czech Republic - Kappa scheme. I dette prosjektet vil det bli utviklet redskap som skal hjelpe oss å; a) forstå de sosiale mekanismene som ligger til grunn for den sårbarheten overfor de klima-endringer vil opplever i naturlig og dyrket skog; b) identifisere tiltak som leder til en effektiv tilpasning til og evnt. avbøting av konsekvensene av slike klima-endringer; og c) skape en bedre forståelse av hvilke tiltak som kan gjennomføres for å øke skogens evne til å fange og lagre karbon. I studien vil det bli fokusert på Tsjekkiske skoger, men en kan se for seg at det blir gjort en tilsvarende studie i Norge som kan danne grunnlag for en sammenligning.

7. Avtale om arbeidsbetingelser ved fakultetet; produksjon og produktivitet

6.1 Avtale

I 2004 ble Gruppen for systemdynamikk fristilt fra Institutt for informasjonsvitenskap og administrativt knyttet til Institutt for geografi, - men da med en egen budsjettpost ved SV-fakultetet på linje med instituttene. I en avtale (se vedlegg 1) som regulerer samspillet GSD, instituttet og fakultetet, blir arbeidsbetingelsene ved GSD fastsatt. Her heter det at;

«Eventuell replassering av stillinger i forskningsgruppen for systemdynamikk er *som for alle fakultetets fagmiljø* avhengig av gruppens studiepoengproduksjon og forskningsaktivitet»!

Denne avtalen blir ignorert av fakultetsledelsen som, i fakultetsstyret, hevder at en slik avtale kan endres med et pennestrøk. Realiteten er at fakultetsledelsens manglende respekt for inngåtte avtaler vil føre til at GSD i nær fremtid blir lagt ned. Vi mener at dette er stikk i strid med UiB sin strategiske satsing på SDGs, på en helthetlig, integrert, tverrfaglig innfallsvinkel til global utvikling og på digitalisert, global kunnskapsformidling, - tre satsingsområder der Gruppen for systemdynamikk ligger i front.

I et vedtak fattet av rådet ved Institutt for geografi (vedlegg 2), fremgår det at fakultetsledelsen ansees forpliktet av inngåtte avtaler der instituttet er en part, og at GSD skal behandles på linje med fakultetets øvrige fagmiljø. Dette vedtaket er ikke blitt lagt fram for fakultetsstyret.

6.2 Bemanning, produktivitet og forholdet til fakultetet

Gruppen for systemdynamikk (GSD) omfatter 3 professorer:
Professor Pål I. Davidsen
Professor Erling Moxnes
Professor Birgit Kopainsky

16 Ph D kandidater, hvorav 13 er eksternt finansierte, svarende til en årlig verdi av ca. 13 mill NOK.

Tabellen nedenfor viser produktiviteten ved Gruppen for systemdynamikk (GSD) relativt til SV-fakultetet;
- den tre-årige gjennomsnittlige produksjon av studiepoeng og Ph D kandidater som skal inngå i rekrutteringsmodellen;
- den kortsiktige produksjon av studiepoeng (2017) og Ph D kandidater (2016 – 19) som legges til grunn for driftsbevilgningen;
- driftsbevilgningen;
- publikasjonspoengproduksjon; og
- BOA-inntekter for 2016- 17.

Langsiktig produksjon av studiepoeng og Ph D kandidater per ansatt (3-årig gjennomsnitt), -grunnlaget for rekrutteringsmodellen:			
Program	**GSD**	**SV-fak**	**Relativ Produktivitet SDG / SV-fak**
Master	31	17.79	**1.78**
Ph D	0.23	0.18	**1.27**
Kortsiktig produksjon av studiepoeng og Ph D kandidater per ansatt -grunnlaget for driftsbevilgningen:			
Program	**GSD**	**SV-fak**	**Relativ Produktivitet SDG / SV-fak**
Master	34.5	18.4	**1.88**
Ph D (2017)	0.67	0.15	**4.46**
Ph D (2018)	1.00	0.15	**6.66**
Ph D (2019)	1.66	0.15	**11.1**
Driftsbevilgning 2019 per ansatt; - en gjenspeiling av produktivitet:			
År	**GSD**	**SV-fak**	**Relativ Produktivitet SDG / SV-fak**
2019	370 000 NOK	160 000 NOK	**2.26**
Publikasjonspoeng per ansatt:			
År	**GSD**	**SV-fak**	**Relativ Publiering SDG / SV-fak**
2017	4.00[1)]	2.77	**1.44**
BOA inntekter per ansatt (utover 13 mill NOK i internasjonal stipendfinansiering av Ph D kandidater):			
År	**GSD**	**SV-fak**	**Relativ BOA-inntjening SDG / SV-fak**
2016	772 000 NOK	459 000 NOK	**1.68**
2017	943 500 NOK[1)]	536 000 NOK	**1.76**

1) I 2016/17 var GSD, pga sykdom, bemannet med kun to personer.

De røde tallene i tabellen over viser at Gruppen for systemdynamikk er langt mer produktiv enn fakultetsgjennomsnittet. Dette gjenspeiles i en driftsbevilgning som ligger på 2.26 ganger fakultetsgjennomsnittet. I fakultetsledelsens fremlegg til budsjett for 2019 fremgår det *helt feilaktig* at GSD «har en overdekning med 0.1 årsverk». I realiteten skyldes denne feilaktige

fremstillingen at gruppen i 2004 aldri fikk med seg den «grunnbevilgningen» som ellers kommer alle andre fagmiljø til gunst gjennom deres institutt-tilknytning.

Medregnes en slik «grunnbevilgning», fremstår den faktiske underbemanningen av GSD på 1.3 ansatte. Faktum er at fakultetsledelsens beregningsmåte krever hver av de ansatte ved GSD må arbeide ca. 2.5 ganger fakultetets- gjennomsnittet, for å kunne legitimere et krav på en stilling, - som kun vi gi en avlastning på 33% for hver ansatt. *En slik forskjellsbehandling er i strid med den inngåtte avtalen og er ikke til å leve med. Arbeidsbetingelsene gjør det umulig å rekruttere kvalifiserte medarbeidere, - enten det er i en ny stilling eller til erstatning for personer som går av.*

6.3 Konklusjon

Gruppen for systemdynamikk (GSD) yter et vesentlig bidrag til UiB sin utdanning og forskning innen SDG, systemanalyse og digital undervisning. Gruppen arbeider under betingelser som er uforenlig med det bidraget gruppen yter. Ledelsen ved SV-fakultetet overholder ikke den inngåtte avtalen av 2004, gir oss ingen forutsigbarhet og forårsaker derigjennom at gruppen innen kort tid vil bli avviklet.

Det må være av strategisk interesse for UiB sin ledelse at så ikke skjer og at GSD sikres forutsigbarhet og arbeidsbetingelser på linje med UiB´s øvrige ansatte i vitenskapelige stillinger.

Sett i lys av en slik strategisk satsing, vil vi foreslå at vårt 10-årige samarbeid med våre partnerinstitusjoner i Europa, Lisboa, Palermo, Nijmegen og Riga, videreføres innen rammen av European Universities Initiative.

Vedlegg 1:
Avtale mellom SV-fakultetet, Institutt for geografi og Gruppen for systemdynamikk.

DET SAMFUNNSVITENSKAPELIGE FAKULTET

Arkivkode:

Sak nr.: 2004/ 6393

Fak.sak: 098/2004

Møte: 28.09.2004

AVTALE OM OVERFØRING AV FORSKNINGSGRUPPE FOR SYSTEMDYNAMIKK TIL INSTITUTT FOR GEOGRAFI

Bakgrunn

Ved Institutt for informasjons- og medievitenskap har det siden etableringen av instituttet ved årsskiftet vært ført drøftinger mellom instituttleder og den vitenskapelige staben om den faglige profilen ved instituttet. En konsekvens av disse drøftingene var at forskningsgruppen for systemdynamikk, i lys av de strategiske planene ved instituttet, ikke fant tilstrekkelige rammebetingelser til å kunne videreføre sine undervisnings- og forskningsoppgaver ved det nye instituttet. Forskninsgruppen består i dag av professor Pål Davidsen, professor Erling Moxnes og førsteamanuensis Ali Kerem Saysel.

På grunnlag av dialog mellom forskningsgruppen, institutt- og fakultetsledelse var det enighet om at den beste løsningen for alle involverte parter ville være om forskningsgruppen kunne føre samtaler med andre aktuelle fagmiljø ved fakultetet med sikte på en eventuell overføring av stillinger, undervisningsopplegg og forskningsoppgaver. Forskningsgruppen var i samtaler både med Institutt for geografi og Institutt for økonomi. Konklusjonene på disse drøftingene var at det var grunnlag for en overføring til Institutt for geografi.

Avtale om overføring

Fakultetsledelsen har med utgangspunkt i samtalene mellom Institutt for geografi og forskningsgruppen for systemdynamikk forhandlet fram forslag til avtale om overføring. Avtalen tar utgangspunkt i at eksisterende ressurser til systemdynamikk ved Institutt for- informasjons og medievitenskap overføres til Institutt for geografi, men slik at forskningsgruppen for systemdynamikk utgjør en separat budsjettenhet. Utover tilførsel av et nytt postdoktorstipend til Institutt for geografi innebærer forslag til avtale ingen ressursforsterkning til noen av miljøene:

Forslag til avtale medfører at:

- Ansettelsesforholdet for professor Pål Davidsen, professor Erling Moxnes og førsteamanuensis Ali Kerem Saysel fra Institutt for informasjons- og medievitenskap til Institutt for geografi med virkning fra 01.10.04.:
- Overføringen av stillingene skal ikke påvirke Institutt for geografi sitt ressursgrunnlag. Forskningsgruppen for systemdynamikk framstår som en separat enhet i budsjettmodellen. Eventuell replassering av stillinger i forskningsgruppen for systemdynamikk er som for alle fakultetets fagmiljø avhengig av gruppens studiepoengproduksjon og forskningsaktivitet.
- De ansatte i forskningsgruppen for systemdynamikk skal kunne velges til instituttets organer på samme måte som instituttets øvrige ansatte. Unntaket er

for vervet som instituttstyrer som skal ha sitt utspring fra geografi. Gruppen skal være garantert observatørstatus med møte- og talerett i instituttstyret.

- Overføringen medfører at Gruppen for systemdynamikk fortsatt får disponere undervisningsarealer i rom 1030 og 1040 i Stein Rokkans hus. I 2004 foretar fakultetet utskifting av maskiner og innkjøp av flatskjermer til disse labene. Deretter tilføres gruppen årlige budsjettmidler til drift og oppgradering av utstyr etter nærmere avtale mellom instituttet og fakultetet. Instituttet får også etter nærmere avtale tilgang til pc-stuer i Ulrike Pihls hus for gjennomføring av laboratorieeksperiment.
- Ordinære driftsmidler tildeles gruppen etter de kriterier som ligger til grunn i fakultetets budsjettmodell.
- Doktorgradsstudenter knyttet til systemdynamikk vil fortsatt kunne disponere kontorarealer i 5. etasje i Lauritz Meltzers hus. Eventuelle nye doktorgradsstudenter vil få kontor ved Institutt for geografi.
- Alle budsjettmidler fordelt til Gruppen for systemdynamikk i 2004 blir overført til Institutt for geografi, herunder også lønnsmidler til studentassistanse. Belønningsmidler for aktiviteter i 2004 som først blir utbetalt i 2005 skal også overføres til gruppens budsjett.
- Gruppen for systemdynamikk får administrative tjenester levert fra fellsadministrasjon for geografi og sosialantropologi. Fakultetssekretariatet vil bistå med ressurser knyttet til internasjonale studiesaker (veiledning, opptak, innpassing) for systemdynamikk.
- Institutt for geografi tilføres en 3-årig postdoktorstilling i geografi med undervisningsplikt.

Styret ved Institutt for geografi godkjente i møte 02.09.04 forslag til avtale.

FORSLAG TIL VEDTAK:

Styret for Det samfunnsvitenskapelige fakultetet overfører ansettelsesforholdet for professor Pål Davidsen, professor Erling Moxnes og førsteamanuensis Ali Kerem Saysel fra Institutt for informasjons- og medievitenskap til Institutt for geografi med virkning fra 01.10.04.

Alf Erling Risa
dekanus

Lise Gundersen
fakultetsdirektør

20.09.04//TT

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Vedlegg 2:

Behov for avklaring av prinsipper for bemanning av Gruppen for systemdynamikk

Vedtak:
Instituttrådet ved institutt for geografi har i møte 25/3 gjort følgende vedtak:

Gruppen for systemdynamikk har stor relevans for Universitetet i Bergen sine strategiske satsinger. Derfor understreker instituttrådet den rollen som Gruppen for systemdynamikk spiller i oppfyllelsen av

- fakultetets målsettinger for utdanning, forskning, og inntekter; og
- universitetets strategiske målsettinger.

Miljøet for systemdynamikk ved UIB med Masterprogrammet og doktorgradsundervisning har en unik posisjon internasjonalt, og kan bare sammenlignes med miljøet ved Massachusetts Institute of Technology. For å bevare denne posisjon og ivareta både de omfattende faglige aktiviteter, og hensynet til HMS- og HR-perspektiver og rettigheter for gruppens forskere, er det behov for forutsigbarhet for bemanningen for årene som kommer.

Som det fremgår av Vedlegg 1, er gruppen svært produktiv, men har over lang tid vært underbemannet relativt til fakultetets øvrige fagmiljø. Underbemanningen henger sammen med at gruppen har falt utenfor den rekrutteringsmodellen som benyttes ved fakultetet. Dette er uheldig for Gruppen for systemdynamikk som dermed mister forutsigbarhet og for fakultetet som må spesialbehandle gruppen. Sett på denne bakgrunnen, fremmer instituttrådet to alternative forslag til prinsipper for bemanning for gruppen for systemdynamikk og ber fakultetsstyret om å vedta ett av disse prinsippene.

1. Strategisk forankring av Gruppen for systemdynamikk

Virksomheten ved Gruppen for systemdynamikk omhandler studiet av komplekse, dynamiske systemer og er plassert helt sentralt i UiB sin strategiske satsing på ***tverrfaglighet***, ***bærekraft*** og ***digitalisering***:

Gruppen utvikler og gjør bruk av teori, metoder, teknikker og verktøy, herunder modellering, simulering og analyse, i sine studier. Videre utvikler og evaluerer gruppen strategier og prinsipper for beslutningstaking i slike systemer. Som illustrert av OECD foreligger det et betydelig behov for ***systemtenkning på tvers av fag og samfunnssektorer***:

> "Governments that have spent decades perfecting systems that can successfully manage complicated problems (such as banking regulation, trade treaties, and healthcare systems), now find themselves immersed in a world of complex problems. -- Traditional management tools have limited capabilities when applied to complex problems. For the sake of expediency, manageability, and clarity, traditional approaches simplify complex problems into what are considered to be its

constituent parts and manage them through discrete interventions, layered one on top of another. However, by looking at actors and interventions in isolation or disconnected from past efforts, complex policy legacies may fail to be captured and addressed. -- Applying a systemic lens to complex problems is useful to map the dynamic of the system underpinning it, how the relationship between system components affect its functioning, and what interventions can lead to better results. System thinking help understand how systems are structured and how they operate." (OECD, 2017, s. 12-15)[8]

Gruppen innretter sin anvendelse av systemdynamikk på ***FNs integrerte bærekraftmål*** (Agenda 2030), WHO´s helsemål ogUNEP´s mål for samspill mellom menneske og natur. Dette er mål som EU har gitt sin fulle tilslutning til i sin etterspørsel etter «policy assessment strategies, methods and tools». Gruppen gjennomfører studier innen befolkningsutvikling, landbruk, samfunnsmedisin, utdanning, økologi, ressursforvaltning herunder marine ressurser, energi og klima. Dette gjøres bl.a. i samarbeid med UNEP, Millennium Institute (NGO), Climate Interactive (NGO) og med en rekke universiteter. Gruppen bidrar i to Horizon 2020 prosjekter og to NFR prosjekt på disse feltene. En Marie Curie søknad innen rammen av Agenda 2030, koordinert av gruppen, er under behandling i EU.

Gruppen arbeider på den internasjonale utdanningsarenaen med EU- og SIU-finansierte universitetssamarbeid på master og doktorgradsnivå. I en forlengelse av dette, formidler gruppen nett-basert systeminnsikt i form av modell-baserte interaktive læremiljø (ILM) og MOOCer basert på en ***digitalisering av undervisning***. Gjennom sitt samarbeid med isee Systems disponerer gruppen et programvareverktøy som tilbyr en sømløs overgang mellom modellering og digital formidling. Gruppen ligger, med sine interaktive læremiljø, helt i forkant av digitalisert, global, og fossilfri undervisning, - ikke minst rettet mot land i utvikling. Gruppen koordinerer en Erasmus+ Strategic Partnership søknad fra seks europeiske partnerinstitusjoner, herunder tre partnere som gruppen samarbeider med i sin European Master in System Dynamics. Prosjektet vil utvikle en rekke ILM-baserte MOOCer med det siktemål å tilby etterspurt undervisning i systemtenkning og modell-basert analyse.

2. **Prinsipper for bemanning**

Når det gjelder prinsipper for bemanningen ved Gruppen for systemdynamikk tar instituttrådet utgangspunkt i "Avtale om overføring av forskningsgruppe for systemdynamikk til institutt for geografi", fra 28.09.2004 (Vedlegg 3) som sier:

"Overføringen av stillingene skal ikke påvirke Institutt for geografi sitt ressursgrunnlag. Forskningsgruppen for systemdynamikk framstår som en separat enhet i budsjettmodellen. Eventuell replassering av stillinger i forskningsgruppen for systemdynamikk er som for alle fakultetets fagmiljø avhengig av gruppens studiepoengproduksjon og forskningsaktivitet."

[8] OECD (2017). Working with change: systems approaches to public sector challenges. OECD Observatory of Public Sector Innovation. An initiative of the OECD's Public Governance and Territorial Development Directorate. Paris.

Instituttrådet ser for seg to alternative prinsipper for oppfylling av denne avtalen:

Forslag a:

Gruppen for Systemdynamikk får tildelt grunnbevilgning i rekrutteringsmodellen på linje med fakultetets institutter slik at gruppen behandles i henhold til den siterte overførings-avtalen.

- Forslaget innebærer ingen endring i budsjettmodellen, bare at den benyttes med tallmessige antakelser slik overføringsavtalen tilsier.
- Instituttrådet foreslår at gruppen skal få grunnbevilgning per ansatt tilsvarende gjennomsnittet for fakultetet.
- Instituttrådet er innforstått med at budsjettmodellen ikke skal benyttes til alloker-inger mellom grupper på instituttene; men denne begrensningen kommer ikke til anvendelse ettersom gruppen for systemdynamikk i følge avtalen skal framstå "som en separat enhet i budsjettmodellen".

Forslag b:

- Ved hver budsjettbehandling underrettes fakultetsstyret om gruppen for system-dynamikk sin faktiske produktivitet. Den skal uttrykkes i antall studentårsverk fullført og i antall PhD kandidater som har disputert (3-årig snitt per ansatt). I tråd med den reviderte rekruteringsmodellen av 11.09 2018, kan begrepet produktivitet utvides til å inkludere også andre forhold som tillegges vekt, så som ekstern finansiering og strategisk satsing. Så sammenlignes målet for produktivitet per ansatt med tilsvar-ende produktivitet for de instituttene som, ifølge rekrutteringsmodellen, ligger an til å få tildelt nye stillinger. Dersom gruppen for systemdynamikk er konkurransedyktig, tildeles Gruppen for systemdynamikk en stilling.

Begge forslag gjør administrasjonen ved fakultetet mer effektiv og ryddig, og de vil begge skape trygghet for fag og arbeidsplasser ved Gruppen for systemdynamikk. Særlig viktig er dette for prof. Birgit Kopainsky som skal lede gruppen med dens mange aktiviteter, og som skal overbevise framtidige medarbeidere om at Universitetet i Bergen er en egnet institusjon for videreføring av faget og dets bidrag til undervisning og forskning ved Universitetet i Bergen.

Vedlegg 3:

a.
UNEP prosjektet; "African Coexistence Landscapes: Securing Their Future for People, Elephants and other Wildlife".

b.
KAZA TfCA: "Master Integrated development Plan".

Vedlegg 4:

MARIE CURIE søknad:
"SDG IMPAKT: Sustainable Development Goals:
Integrated Model-Based Policy Analysis and Knowledge Transfer"

Vedlegg 5:

Council for Science and Technology, Government Office for Science, UK:

“Computational Modeling: Technological Futures:
Chapter 1; Why Model?”

Vedlegg 6:

Uttalelse til rektor ved UiB fra Prof. John D. Sterman, Sloan School of Management, MIT:

Vedr. behovet for opprettelse av et tverrfaglig bachelorprogram med utgangspunkt i systemdynamikk.