I. GENERAL COURSE INFORMATION

VIRGINIA TECH  
NORTHERN VIRGINIA CENTER  
GRADO DEPARTMENT OF INDUSTRIAL & SYSTEMS ENGINEERING

ENGR 5104       APPLIED SYSTEMS ENGINEERING: System Dynamics and Systems Thinking

Fall 2012
Dr. Hazhir Rahmandad
Last Update: August 15, 2012

Course Description

Why do so many business strategies fail? Why do so many others fail to produce lasting results? Why do many businesses suffer from periodic crises, fluctuating sales, earnings, and morale? Why many social and governmental programs fail to achieve their desired objectives and some create results counter to their goals?

To address these questions, in this course the basic concepts of systems thinking and system dynamics modeling will be introduced. In general, systems’ thinking is a school of thought that focuses on recognizing the interconnections among the parts of a whole entity (the system) and synthesizing the interconnections into a unified view of the whole entity (the system).

System dynamics is a modeling process to quantify problems that unfold through time in mathematical models that are simulated to investigate sources of undesirable dynamics and find successful improvement strategies. System dynamics embodies an iterative process in which a problem that is pervasive throughout a system is defined, the structure of the system that generates the problem will be studied, and policies or practices that can change the system structure and behavior and therefore alleviate/solve the problem will be reviewed and introduced.

The understanding of the system structure requires the determination of how critical variables affect other variables, even if the other variables are downstream from the critical variables under consideration. To determine variable interrelationships, not only must the analyst establish the causal relationships among the elements of the system but also distinguish those among the physical, organizational, and decision-making relationships.

In this course, you will consider problems that manifest themselves in complex systems. Examples of these include but are not limited to: the performance degradation associated with the introduction of new technologies in organizations, the congestion associated with transportation networks, the lack of process performance improvement when introducing quality improvement interventions, fluctuating sales, production and earnings; the diffusion of new technologies; environmental challenges, and epidemics. You will use one of several simulation
software packages throughout the course to understand, evaluate, and improve upon complex problems and establish a relationship between the real world and a virtual simulation world by generating and evaluating corresponding system simulation models.

**Course Learning Objectives**

- Appreciation for systems thinking, causal loops, stocks and flows and feedback dynamics.
- Define a problem, a system and hypothesize its behavior that is responsible for the problem.
- Use of behavior over time graphs.
- Identify the physical, organizational, decision-making structures within systems.
- Identify critical variables in a system and their relationships to other variables.
- Draw and interpret causal loop and stock and flow diagrams.
- Identify and define stocks and flows.
- Formulate robust, small, models.
- Define the dynamic behavior of systems.
- Identify and define delays in systems.
- Conduct preliminary policy analysis using simple dynamic models.
- Conduct basic model validation steps.
- Develop and test models using simulation software. (Vensim the primary tool for the course)
- Appreciate of how stock-and-flow and feedback structures containing delays and non-linear relationships can create non-intuitive behaviors over time, and therefore demand simulation for better thinking about, and solutions to, dynamically complex problems.
- Become in-house trainers of system dynamics principles and modeling basics.
- Become a discriminating user of dynamic models.

**Prerequisites**

Graduate standing in the industrial and systems engineering degree programs. (3H, 3C)

**Professor**

Hazhir Rahmandad  
Office: Falls Church Center, Room 430  
Phone: 703.538.8434  
Office Hours: Mondays 5:30-6:30 pm  
E-mail: hazhir@vt.edu

**GTA**

Mohammad Jalali  
Office: Falls Church Center, Room 433  
Phone: 703.538.3765  
Office Hours: Tuesdays 6:30-8pm  
E-mail: mj@vt.edu  
Skype ID: Jalali.ie

**Class Meeting Time and Place**

Monday: 7 p.m. - 9:45 p.m.  
Blacksburg: Whitt 281  
Falls Church: 113

**Class video website:**
Accommodations

Students are encouraged to address any special needs or special accommodations with me during the first two weeks of the semester, or as soon as you become aware of your needs. Those seeking accommodations based on disabilities should obtain a Faculty Letter from the Services for Students with Disabilities office (540-231-0858) located at 250 S. Main Street Suite 300 (Kent Square).

Required Texts


Supplementary Texts and Readings (Not Required)


In addition, modeling software will be used in the course. Several excellent packages for system dynamics simulation are now available commercially, including iThink, from High Performance Systems, Powersim, from Powersim Corporation, Anylogic from xjtek, and VENSIM, from Ventana Systems. All are highly recommended. You may wish to learn more about these packages, as all are used in the business world and potential employers are increasingly seeking expertise in them. For further information, see the following resources:


Powersim: See the Powersim web site at http://www.powersim.no

Anylogic: See xjtek website at http://www.xjtek.com/

VENSIM: See the Ventana Systems web site at http://www.vensim.com/

In this course, the VENSIM Personal Learning Edition (VENSIM PLE), a FREE package offered by Ventana Systems will be used. VENSIM PLE is available for both Windows and Macintosh. Models created with it are
fully convertible across platforms. VENSIM PLE comes with on line user’s guide and help, and also a folder of demo models. Download VENSIM PLE from the VENSIM web site at http://www.vensim.com/freedownload.html

Course References:

The systems thinking and system dynamics literature has a plethora of reference materials since it spans over forty years of academic and empirical work. The references presented in Appendix D have provided some of the background information that serves as the foundation of the course. You are encouraged to consult these references and other materials that complement the following reference list. An extensive library of references in system dynamics can be found for free at: http://www.systemdynamics.org/biblio/sdbib.html

II. OUTLINE OF TOPICS AND READINGS

Class Structure
This course is organized based on the principals of Team-Based-Learning (TBL). Using TBL allows for greater involvement of students in the learning process through multiple hands-on exercises on each topic and team-based problem solving. In fact about half of the class time will be spent on using the concepts of the course for solving practical problems. The benefits of this approach include reduction in homework, greater participation during the class, more active learning, and provision of faster feedback. TBL requires students to 1) Do the reading assignments seriously. The teaching of course material will focus on addressing questions you have after the reading (and in some cases watching short instructional videos), not discussing them for the first time. 2) Work on the assigned challenges to find out what you don’t know after readings (sample solutions to challenges are provided on a weekly basis). 3) Actively participate in classroom discussions and team activities.

ENGR5104
Fall 11- Mondays 7-9:45 pm

Reading assignments are not final and may change up to one week to the date of the assignment.

<table>
<thead>
<tr>
<th>Date</th>
<th>Class</th>
<th>Topic</th>
<th>Reading to complete before the session</th>
<th>Proj. Update</th>
<th>In-class Team Quiz</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/27</td>
<td>1</td>
<td>Course Overview; Team Selection; System dynamics overview: SARS case;</td>
<td>Syllabus; GHS Constitution (<a href="http://ghs.graduateschool.vt.edu/ghs_constitution.html">http://ghs.graduateschool.vt.edu/ghs_constitution.html</a>) Business Dynamics [BD], Ch.1 (Chg P14)</td>
<td>Start Project</td>
<td></td>
</tr>
<tr>
<td>9/3</td>
<td>2</td>
<td>The Beer Game: Part one</td>
<td>Read BD, Ch. 3, Ch. 4 (Chg P117) Do the Vensim Tutorial (On SCH, session 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/10</td>
<td>3</td>
<td>The Beer Game: Part two: Results; Systems thinking and system dynamics tools: Part 1: Reference modes and problem definition, Part 2: Building theory with causal loop diagrams</td>
<td>Read BD, Ch. 5 (Chg P145, Chg P147, Chg 176) (Skim sections 5.4, 5.6)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Date</td>
<td>Page</td>
<td>Title</td>
<td>Reading Suggestions</td>
<td>Mid Term Project Reports</td>
<td>Notes</td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------</td>
<td>--------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>9/17</td>
<td>4</td>
<td>System Dynamics Tools Part 3: Mapping the stock and flow structure of systems; Dynamics of Stocks and Flows</td>
<td>Read Ponzi’s story: <a href="http://en.wikipedia.org/wiki/Charles_Ponzi">http://en.wikipedia.org/wiki/Charles_Ponzi</a>  <a href="http://en.wikipedia.org/wiki/Ponzi_scheme">http://en.wikipedia.org/wiki/Ponzi_scheme</a>  Read BD, Ch. 6 (Chg P201, Chg P213, Chg P214)  (Skim sections 6.2.7, 6.2.8, 6.2.9, 6.3.4, 6.3.6)  Ch. 7 (Chg P239)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/24</td>
<td>5</td>
<td>System Dynamics Tools Part 4: Linking feedback with stock and flow structure</td>
<td>Read BD Ch. 8 (Chg P281-2, Chg P286), Appendix A (Chg P910)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>10/1</td>
<td>6</td>
<td>System Dynamics Tools Part 5: Material and Information Delays, Co-flows and Aging Chains</td>
<td>Critical to read BD Ch 11 (Chg P425-426, Chg P435) and Ch 12 (Chg P495-7, Chg P503-4)</td>
<td>3 (Mid Term Project Reports)</td>
<td></td>
</tr>
<tr>
<td>10/8</td>
<td>7</td>
<td>Dynamics of Growth: Epidemics, diffusion and modeling the growth of new products; Network externalities, complementarities, and path dependence;</td>
<td>Read BD Ch. 9.1 (Skim 9.1.2, 9.1.3); 9.2, 9.3 (Skim sections 9.3.5 - end) (Chg P310 part 1, Chg P335-337 part A)  Read BD Ch. 10 (Skim section 10.2)(Chg P403)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/15</td>
<td>8</td>
<td>Modeling decision making: Formulating and testing robust models of business processes, modeling supply line</td>
<td>Read BD, Ch. 13; 14.1 (Chg 521-522; Chg529; Chg 533-34; Chg 547;</td>
<td>Mid Term Project Critiques Due</td>
<td></td>
</tr>
<tr>
<td>10/22</td>
<td>9</td>
<td>Modeling Process-Future Electronics Case</td>
<td>Future electronics case (on SCH; only read the case to be familiar with it, no need to start modeling)  BD Sections 14.2-14.5  Chg 566-67; Chg 575-76; Chg 583-84</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10/29</td>
<td>10</td>
<td>Managing Instability: Supply chains, forecasting and feedback</td>
<td>Read BD, Ch 16, and Sections 17.1, 17.2 and 17.3  Chg 683</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>11/05</td>
<td>11</td>
<td>Projects, Products, and Processes: The dynamics of project management—On time and under budget Process improvement and product development</td>
<td>Read BD, Sections 2.3 and 6.3.4  Lynies and Ford 07  Chg 656-658</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/12</td>
<td>12</td>
<td>Model analysis, modeling tips, management flight simulators</td>
<td>Read BD Chapter 15 (Chg 615), Sections 18.1, 18.2 (Chg 718-720; Chg 741-742 (till part 4))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/19</td>
<td></td>
<td><strong>Thanks Giving</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Reading Assignment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/26</td>
<td>13</td>
<td>Dynamics of health care system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/03</td>
<td>14</td>
<td>Applications of System Dynamics to Environmental and Public Policy Issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/10</td>
<td>15</td>
<td>Truth and beauty: building confidence in models, Being a savvy user of models</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Holiday, No Classes**

**Final Report (Nov 25th)**

12/03  | 14 | Applications of System Dynamics to Environmental and Public Policy Issues           |
|       |    | Limits to growth 30 year update (introduction and executive summary).               |
|       |    | Danna Meadows short article in Scholar                                             |
|       |    | BD Sections 19.1, 19.2 (Chg 773-4; Chg 778-9)                                      |

**Exam out (Dec 3th)**

12/10  | 15 | Truth and beauty: building confidence in models, Being a savvy user of models      |
|       |    | How to keep learning, follow-up resources and courses                              |
|       |    | Read BD Ch 21 (Chg 871)                                                           |
|       |    | Read BD Ch 22                                                                     |

**Exam Due (Dec 10th)**

**Critiques Due (Dec 12th)**

**BD**: Business Dynamics Text Book  
**Chg**: Challenges from the BD. Note that most models discussed in the text are available in the SD that comes with the book.  
**SCH**: posted on Scholar under the relevant session (unless otherwise noted)

**Reading Assignments**

You should expect to read each assignment from Sterman thoroughly. I also expect to record and share some additional instructional videos to help you learn the basic concepts. Set aside 3-4 hours per week for this reading, watching, and working on the related exercises. Reading Sterman is like reading a calculus book in that you will need to ponder over equations, graphs, and diagrams. This is when you are expected to grasp the basic concepts so that you are ready to discuss them in the class, ask questions, and solidify your knowledge. You need to assess your understanding and find out about your questions by working on the “Challenges” in BD. You are expected to at least tackle the challenges specified in the reading list (Look for “Chg” and page number). The class time is spent largely on applying the concepts and answering your questions rather than repeating what you have read in Business Dynamics or watched on the videos, therefore skimping on the readings will have a serious negative impact on your learning.

**Team Exercises**

A large part of class time is spent on exercises based on the material you have covered in your readings. You work on these exercises both individually and as a team, and three of these exercises (identified as team quiz) will be graded. Your team’s active participation in exercises as well as your performance in the team quiz items determine your team’s participation grade. Moreover these exercises are where you can really learn the skills introduced in this course and all the nuances involved.

**Final Exam**

Final exam will be take-home, open book, and individual based. The exam questions will be released through the Scholar after the class on December 3th, and will be due before the start of the last class on December 10th.

**Peer Evaluation of Team-member Participation**

At the end of the course you will have the opportunity to evaluate your team-mates. This Peer Evaluation is confidential and will consider how well your team-mates prepared for the team tests and their overall contribution to the in-class exercises and the mid-term project review. For peer evaluation you each assign a total of N*10 points to the other N members of your team (for a team of N+1 people). Raters must differentiate some in their
ratings (this means each rater would have to give at least one score of 11 or higher, with a maximum of 15, and at least one score of 9 or lower). As a result team peer evaluation will produce differences in grades only within teams. Consequently team members can’t help everyone in their team get an A by giving them a high peer evaluation score. The only way for everyone in a team to earn an A is by doing an outstanding job on the individual and team tests and assignments. Usually team evaluation has a significant impact on the overall grade, therefore you need to make sure you keep your team-mates happy.

Instructor Assessment of Individual Participation
Another part of grade relates to individual participation in the course. This part of the grade depends on individuals’ active participation in classroom discussion, asking questions, presence in the sessions, and contribution to overall group learning.

III. Personal Project and Project Critique Description

Overview
The goal of the personal project is to provide an opportunity to apply the skills you learn in this course to a problem that you care about. The main value of the project is in practicing systems thinking and system dynamics modeling in a step-by-step process during the semester. The project is relatively small in scope and workload, moreover the idea is for you to focus on a problem of interest to you, therefore projects are individual based. The project critique provides you with an opportunity to critique other projects in terms of quality of model, analysis and modeling process, generation of insights, and clarity of presentation. The critique makes you a more cognizant user of models and helps you improve your own modeling capabilities. There are two critiques that you will undertake, the first critique does not impact grading and is supposed to provide mid-way feedback. The second critique is more formal, anonymous, and impacts grading.

Process
Different steps of the project are distributed through Scholar during the semester. You are encouraged to submit a short project update on the weeks specified on the syllabus. These updates do not impact the final project’s grade, however, they provide you with an opportunity to receive feedback from the instructor, TA, and your team-mates on your project. They also help keep you on the right pace to finish your project on time. While the instructor and the TA periodically review the submitted interim reports on scholar, if you have specific questions or require feedback on your work, please send an e-mail to both the instructor and the TA with your question and latest model and report. Moreover, your report number 3 is going to be reviewed by one of your team-mates. The final project report and model are due on November 25th, 11:59pm. Late projects are not accepted. Instructions for preparation of final project report are discussed below, please follow these instructions carefully.

Each of you will be randomly assigned to critique three final project reports and their accompanying models. This critique process is double-blind (the author of the report and the reviewer will not know each others’ identity). Critiques assess the quality of model, analysis and modeling process, generation of insights, and clarity of presentation. Instructions for submission of project critiques are discussed below. Critiques are due on December 12th, by 11:59pm. Late critiques are not accepted.
Project critiques are graded as pass/fail. Critiques that do not include detailed assessments of different aspects of the project under consideration will fail. Critiques of the same project are expected to correlate with each other, large deviations from two other critiques may lead to failing of a critique. The project grades are calculated based on the average of the project grades provided by project critiques, combined with instructor’s evaluation of different projects. Only those critiques that have passed will be included in the averaging.

A set of common questions regarding the projects and critiques along with their answers are available in Appendix C.

Project Updates

The format and content of project updates are flexible. All the reports, including the final one, should be submitted to the personal Dropbox folder on the Scholar website. You are advised to follow the Personal Project Guides posted on the Scholar in terms of content to be discussed in each update. Your third report will be reviewed by one of your team-mates as described in the personal project guide number 3, and he/she is expected to provide you with feedback. You should consider the quality of the feedback you have received as part of your evaluation criteria for your team-members in the final team member evaluation. The instructor will use your uploaded project updates to discuss common challenges and provide suggestions for how to deal with them. If you need specific feedback, contact the instructor and that TA directly through phone or E-mail with your question.

Project Report and Model

The project report is short and the material is developed during the semester. The final report could in fact be an abbreviated assembly of what you have already put together for shorter progress updates. Project reports can take the form of power-point presentations or papers. The maximum size for the former is 15 slides and for the latter 10 pages (font size 12, times new roman, 1.5 line spacing, margins of 1” on all sides), including pictures. Power point slides can have descriptions on the note page up to 200 words per slide. Longer reports will lose points. Appendix A includes a suggestive framework for the project report.

Submitting the model:
You should submit any simulation model that you develop for your project along with the final project report. Submit a Vensim version of the model. If you are using other software for the development of your models, it should be an easy task to rewrite the final model in Vensim. You can get help from a class mate who has been using the Vensim during the semester. To get their full grade, models should follow all the good modeling practice guidelines discussed during the semester. A model evaluation software will be provided for facilitating some automated features of model evaluation. The checklist for evaluation of project reports discusses some of these items.

Convention for naming and submitting the project report and model:
You will be assigned a unique number to use for submission of your project reports and models. Do not share this number with others to ensure a high-quality review process. The final project report and the final model should be named as xyz.doc (or .pdf, .ppt, .mdl etc) where xyz is your unique submission number. If you need to submit more than one file of the same type, use numbering convention of xyz-1.doc, xyz-2.doc, etc. Your project report and your model should be free of any other identifying information. Please do not include in
your files your name, student ID, E-mail address, or any other information that identifies you as the author of the report or model. Make sure you remove any such information that is automatically included by Word, Powerpoint, or Acrobat by going to file>Properties. **Reports and models with identifying information will lose 20% of their final grade** (however, do not subtract this in your project critique; the instructor will do that).

**Project Critiques**
Projects are evaluated based on four major criteria: quality of model, quality of hypothesis building and analysis, generation of insights, and clarity of presentation. The list in Appendix B describes what questions to ask in order to evaluate a model/project report on each dimension. For each critique you will be reporting four numbers (between 0-10) as well as a written critique that explains major strengths and weaknesses of the project report and model. The written critique is limited to 700 words and should not include figures or special characters because it will be included in the online survey that is submitted for the critique. The average of grades assigned by the three project critiques constitutes the project grade. You will receive the written critiques for your project at the end of the semester. Project critiques will be submitted online through an online survey, to be completed once for each project. Make sure you read the survey before starting the critique so that you know what to look for inside the projects.

IV. COURSE GRADING
Grading weights for different components have been determined based on team’s feedback during the first session.

**Grade Distribution**

<table>
<thead>
<tr>
<th>Grade Distribution</th>
<th>% of Final Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Quizzes and Team Participation</td>
<td></td>
</tr>
<tr>
<td>Final Exam</td>
<td></td>
</tr>
<tr>
<td>Individual Project</td>
<td></td>
</tr>
<tr>
<td>Project Critique</td>
<td></td>
</tr>
<tr>
<td>Instructor Assessment of Individual Participation</td>
<td></td>
</tr>
<tr>
<td>Peer Evaluation</td>
<td></td>
</tr>
</tbody>
</table>

100%

V. ETHICAL FRAMEWORKS

**Honor Code**
All students must adhere to the Honor Code Policies of Virginia Tech. The Honor Code will be strictly enforced in this course. All assignments shall be considered graded work, unless otherwise noted. All aspects of your
coursework are covered by the honor system. Any suspected violations of the Honor Code will be promptly reported to the honor system. Honesty in your academic work will develop into professional integrity. The faculty and students of Virginia Tech will not tolerate any form of academic dishonesty. Please make sure you are aware of the honor code system: [http://ghs.grads.vt.edu/](http://ghs.grads.vt.edu/)

**Principles of Community**

Virginia Tech is a public land-grant university, committed to teaching and learning, research, and outreach to the Commonwealth of Virginia, the nation, and the world community. Learning from the experiences that shape Virginia Tech as an institution, we acknowledge those aspects of our legacy that reflected bias and exclusion. Therefore, we adopt and practice the following principles as fundamental to our on-going efforts to increase access and inclusion and to create a community that nurtures learning and growth for all of its members:

1. We affirm the inherent dignity and value of every person and strive to maintain a climate for work and learning based on mutual respect and understanding.
2. We affirm the right of each person to express thoughts and opinions freely. We encourage open expression within a climate of civility, sensitivity, and mutual respect.
3. We affirm the value of human diversity because it enriches our lives and the University. We acknowledge and respect our differences while affirming our common humanity.
4. We reject all forms of prejudice and discrimination, including those based on age, color, disability, gender, national origin, political affiliation, race, religion, sexual orientation, and veteran status. We take individual and collective responsibility for helping to eliminate bias and discrimination and for increasing our own understanding of these issues through education, training, and interaction with others.
5. We pledge our collective commitment to these principles in the spirit of the Virginia Tech motto of Ut Prosim (That I May Serve).

**Appendix A- Project Report Format**

It is suggested that the project report includes the following sections, however, feel free to use a different presentation structure if you find it more appropriate; after-all your class-mates are the final judge:

**Problem definition/statement and reference modes:** Elaborates on the motivating problem for the project and the important reference modes for how critical variables have been changing over time. Pictures are as useful, if not better than, texts. Given the time constraints, you are discouraged to look for exact numerical data for the reference modes. A qualitative sketch of how things have been changing through time (e.g. increasing, decreasing, oscillating) will suffice.

**Main feedback loops:** The set of important feedback loops, or dynamic hypotheses, which are good candidates for explaining the sources of the problem. Try to generate as many feedback loops as possible, though you can only discuss the major ones in your report.

**Model:** Discuss the stock and flow structure pertaining to the part of dynamic hypotheses you have decided to model. Your model does not need to include all the loops, in fact, it is recommended to only include a few central structures and keep the model simple and focus on analysis. Therefore the model is not expected to generate the historical behavior, rather, to allow you analyze a couple of mechanisms more closely.
Analysis: The analysis section explains 1-Why the model does what it does? How the structure of the model generates the observed behavior? 2- How does the behavior of the model inform the real problem you care about? What are the policy ramifications of the analysis?

Personal Insights: In this section you discuss what you have learned in the modeling process. Insights, new understandings with respect to some aspect of the problem, come at every stage of the modeling process. However, they are fleeting because once you notice them they lose their novelty and therefore their quality as an insight. As a result, it is extremely important to record your insights at every stage of the project, at the very time you have the “Aha!” feeling. Use the progress updates to be submitted with the assignments to identify what you have learnt in the process before it becomes mundane.

Appendix B- Checklist of questions for project critique

These questions provide you with a guideline for how to assess the quality of a project. They therefore are helpful for you in crafting your own project report and in building your own model as well. On each of the four dimensions you will give a assessment between 0 and 10 (10 for a very good project that passes most of the critique questions). Some of the issues on formulation quality can be checked using SDM-Doc software as well. In front of each question I describe whether it applies to your qualitative or simulation model (or both):

1- Model quality (40%)
   Basic tests before simulation:
   Does the model have unit consistency? (Use Model>Units Check in Vensim to test for this) (Simulation model only)
   Are model variables named correctly? (Variables can increase or decrease with a clear direction) (Qualitative and Simulation models)
   Are polarities of different links assigned correctly? (Qualitative and Simulation models)
   Are different loops identified and named properly? (Loops should be identified with Reinforcing or Balancing signs as well as a name) (Qualitative and Simulation models)
   Is model well documented, e.g. variables defined in the comment section of the equation editor? (Simulation model only)
   Model structure tests:
   Are stocks and flows conceptually sound and appropriate for the model purpose? (Qualitative and Simulation models)
   Are the intended feedback loops captured in the model? (Simulation model only)
   Formulation robustness tests
   Are decision rules formulated well? Are they reasonable representations of how decisions could be made in the specific setting? See page 517 of text for specific issues on formulating decision rules. (Simulation model only)
   Are formulations simple enough? For example, it is a good practice to keep the number of inputs into any equation below 3 and avoid complicated equations with embedded If Then Else and Min/Max functions. (Simulation model only)
   Are there any hanging numbers (numerical values used in equations without any explanation, rather than being put in as explicit parameters with units and explanation)?
   Are table functions robust and well formulated? See page 553 of text for specific points on formulation of table functions. (Simulation model only)
Time step test:
Is the model time step short enough. To test this, divide the time step (Go to Model>Settings>Time
Bounds) by two and run the model, if there is a change in behavior of the model, the initial time
step has not been short enough. (Simulation model only)

Model behavior tests:
Does the model start from equilibrium in the base case? (Simulation model only)
Think of a few extreme condition tests (see pages 869-872) and apply them to the model. Does the
model behave robustly, that is, the behavior remains reasonable and in the expected domain?
(Simulation model only)
Do all physical stocks remain positive, or can they go negative? Do stocks have first order controls?
(Simulation model only)

2- Hypothesis building and analysis (30%)
Does the set of dynamic hypothesis (loops and basic structures hypothesized to explain the problem at hand)
look reasonably broad and comprehensive? (Qualitative model only)
Are loops named properly and have the correct sign (Reinforcing or Balancing)? (Qualitative and Simulation
models)
Does the analysis provide a good explanation of why the model behaves the way it does? (Simulation model
only)
Does the analysis provide a good connection between the modeling work and the real world problem which
has motivated the model? (Qualitative and Simulation models)
Are there any discussions of potential improvement strategies? (Qualitative and Simulation models)

3- Generation of insights (15%)
Are the insights of the project documented?
Do you, as the reviewer of the project, find interesting points in the project and modeling work?

4- Clarity of presentation (15%)
Was the report and model clear and understandable?
Did you feel interested to follow the presentation

Appendix C- Frequently Asked Questions for Project, its Report, and Critique
Modeling and Analysis:

Q- I don’t have any table functions in my model. Does that hurt my project grade, given that there is a specific
question regarding table functions in the project evaluation form?
A- No, if your model does not need a table function, you don’t need to worry about it.

Q- I have a very hard time putting my model in equilibrium. What should I do?
A- Finding closed-form solutions for equilibrium value of stocks is the best option in terms of enabling you to do
a good job of analysis. To do that you need to write the equations for equilibrium of each stock and then solve
this N-equation N-Unknown for the initial value of stocks in terms of other parameters etc. However, if you have
a few table functions or non-linear equations, it is possible that finding closed-form solution is too hard for your
model, or too time consuming. In that case you can use an alternative "cheating" method: let the model run for a
long time. The model will probably reach some equilibrium. Write down the value of stocks at that final time and use those as the initial value for the stocks. This will run the model in equilibrium. If you do this, you will note that any change in parameters of the model will change your equilibrium and will require you to run this procedure again and find the new values.

Note that some models don't have non-trivial equilibriums. For example the logistic diffusion model has two equilibriums at 0 and all population having adopted the product, none of which are so interesting or insightful. In these cases you can skip the equilibrium analysis. If your cheating method does not yield any equilibrium or it results in some trivial condition that is not necessarily interesting, then it is possible that your model does not have an informative equilibrium.

Q- In the report, can I discuss what I learnt in terms of modeling process and techniques from the project?
A- Absolutely, your process insights are just as important as issue specific insights. The main goal for the project is helping you build a better understanding about modeling process and how it can be helpful for understanding dynamic issues. So process insights about modeling, pitfalls, and other issues related to that are very legitimate parts of insights in your report.

Q- I'm not sure what time step I should use. In your project review form, it says to divide the time step by 2 and see if any changes occur but I'm not sure how large of a change you mean. There are small changes to my 2 stocks at each time step, so how small should I make my time step?
A- There is always some very small change in the behavior of the model as a result of change in the time step, even if that change is not characterizing a problem with the model. What I mean by change in behavior, is qualitative change, which is observable by eyes when you look at the graphs.

Q- The project review form asks if the model starts from equilibrium in the base case and the equilibrium is calculated in closed form for the initial value of stocks. When I put my system into equilibrium, I have just been multiplying the equations for 3 of my flows by zero; is this ok or do I need some kind of external multiplier or even a separate model for the equilibrium case?
A- Putting all the rates not critical to your problem definition to zero is fine, for example if you are looking at the dynamics of transition from poor to wealthy population states, it is fine to put the birth and death rate to zero (if you can’t find the equilibrium in closed form), however, you should not multiply the rate of change from the stock of poor people to the wealthy ones by zero, rather you should find numerically or analytically, the value for these two stocks that keeps the net rate of change between two at zero. Note that even if multiplying additional rates by zero, I would suggest doing that through an exogenous parameter/factor, which keeps the rates at zero (e.g. by being multiplied into the rates) until some time in the simulation, and then allows them to behave as they are formulated (e.g. by changing into one). This way you can start from equilibrium, but then see the different behaviors in the system arising from the population growth dynamics.

Q- You've spoken so many times of how a stock needs to have an arrow towards its outflow to have control. Is this a necessity?
A- The link does not need to be direct, it can go through several auxiliary variables. The point is that if you have a stock of physical material, its outflow rate should not stay positive if the stock goes to zero itself, so there should be some mechanism to show this impact.

Q- Is it possible that some links will not have a polarity?
A- There are conditions under which the sign of link is not determinable. For example if \( y = x^2 - x \), then at some ranges of \( x \) we have positive sign and at some ranges we have negative in relation between \( x \) and \( y \). Under these conditions it is fine not to put any polarity on the link. In practice however these conditions are not common in our models and I suspect something else is going wrong if you think a large fraction of your links are undeterminable. The potential trick is in that you need to "keep everything else constant" when looking at the impact of one variable on another in a link. For example the impact of body fat on body fat percentage may seem unclear because you may have more body fat but less percentage, however, if you keep the body weight to be fixed, an increase in the stock of body fat will definitely increase the body fat percentage, therefore a positive sign is needed.

**Final Report**

Q- I wanted to put in a Table of Contents in my report. Will that also count as a Page? How about references?
A- You can have a cover page, a table of contents, and a reference list that are not counted in the 10/15 page limited.

Q- In the report do I need to paste the causal loop model?
A- You need to include a picture of the causal loops in your report because the causal loops include a larger model boundary and set of hypotheses than your final simulation model and having the picture simplifies your discussion of these hypotheses.

Q- Should I paste the "Doc" file in Vensim to the final report?
A- No. You submit your documented Vensim (make sure your model has explanations for all the equations) model so no need for further documentation.

Q- Do I need to include the hypotheses (such as the assumption of parameter value) in the report? Or I just include it in comment part of variables of Vensim?
A- You don't need to include them in your report. The comment part is already in the model, so you don't need to repeat what is included there. The same holds for parameter values. However, you need to discuss the hypotheses in terms of feedback loops. You have a problem definition (captured in the reference models, e.g. the defects are increasing, or ...). Then you have several hypotheses that you think may explain this pattern. You have captured these in your causal loops. Those are the hypotheses you need to explain in the report.

Q- I wonder in my report, do I need to describe the decision rule in a separate part? or I can mention it just in a hypothesis and model explanation.
A- Decision rules are the parts of model that describe some human decision-making, e.g. investment function, how people decide to buy the product depending on the quality, etc. You can just discuss them as part of the model description and a short explanation is enough: e.g. the investment is assumed to be fraction of the profit.

Q- How do I remove the identifying information from my word file?
A- Instructions for removal of identifying information depends on the exact software and version, this article provides some details and you can find additional information online, e.g. for office 2010 files.

Q- Can I submit all the files for my project in a single zip file?
A- Sure, that would actually simplify the distribution of files for all of us. Please name the zip file as your personal submission number and make sure all the files zipped inside it follow the same convention.

**Critique**
Q- Why should I care about the quality of my critique?
A- There are two reasons. First, a fair and balanced critique will help us have a more fair and balanced grading for the class, which is in your interest as well. Second, your critiques are graded as pass/fail, and you need to show a reasonably good level of quality in your critique so that your responses correlate well with the other two critiques of the same project. If your critique does not correlate with others, you may get a fail for the grade of that critique and that will impact your overall grade negatively.

Q- When I open the model, it seems that all the variables are mixed together and it is hard to read the name of the variables. What should I do?
A- It sometimes happens that Vensim opens the models differently on different platforms. Just select all the variables in the model (Ctrl-A) and then go to the bottom toolbar and make the font size smaller (e.g. to 10 from 12). That should solve the problem.

Q- I have problem downloading the .mdl files from the website. Any suggestion?
A- right click and save target/link as ... usually works fine (does on my browser, maybe try another browser?). You can also left click and save the text file opened in your browser as .mdl file and it should open fine in Vensim.

Q- I found author's information in the file properties. Do I need to reduce 20% from its grade or I will not consider it and you reduce it?
A- You will have a question to signify that in the online survey which gathers the critique results. You don't need to deduct the grade directly, that will be done by the instructor.

Appendix D- Course References


• Rahmandad, H and J.D. Sterman, (2008). Heterogeneity and Network Structure in the Dynamics of


