System Dynamics Methods: A Quick Introduction

Craig W. Kirkwood Arizona State University

Original material copyright © 1998, C. W. Kirkwood (version 1b – 4/1/98, 5/5/10, 10/8/12, 1/12/13)

Effective January 12, 2013, this work is licensed under a Creative Commons Attribution-NonCommercial 3.0 Unported License.

See http://creativecommons.org/licenses/by-nc/3.0/ for further details.

Vensim is a registered trademark of Ventana Systems, Inc.

Contents

1	\mathbf{Sys}	System Behavior and Causal Loop Diagrams 1					
	1.1	2 Patterns of Behavior 3					
	1.2						
	1.3	Feedback and Causal Loop Diagrams 5					
	1.4	System Structure and Patterns of Behavior 9					
	1.5	Creating Causal Loop Diagrams 13					
	1.6	References 14					
2	\mathbf{A} I	A Modeling Approach					
	2.1	Stock and Flow Diagrams 16					
	2.2	Generality of the Approach 17					
	2.3	Stocks and Flows 17					
	2.4	Information 19					
	2.5	Reference 20					
3	Sin	Simulation of Business Processes					
	3.1	Equations for Stocks 22					
	3.2	Equations for Flows 23					
	3.3	Solving the Equations 24					
	3.4	Solving the Model 25					
	3.5	Some Additional Comments on Notation 25					
	3.6	Reference 27					
4	Bas	Basic Feedback Structures					
	4.1	Exponential Growth 29					
	4.2	Goal Seeking 32					
	4.3	S-shaped Growth 34					
	4.4	S-shaped Growth Followed by Decline 37					
	4.5	Oscillating Process 37					
	4.6	References 40					

5	De	veloping a Model					
	5.1	1 The First Model 44					
	5.2	Performance of the Process 50					
	The Second Model 52						
	5.4	The Third Model 57					
	5.5	The Fourth Model 57					
	5.6	The Fifth Model 62					
	5.7	Random Order Patterns 66					
	5.8	Concluding Comments 71					
	5.9	Reference 71					
6	Da	lana Carathian and Assaurting 79					
6		lays, Smoothing, and Averaging					
	6.1	Pipeline Material Flow Delays 73					
	6.2	Third Order Exponential Delays 75					
	6.3	8 8					
	6.4	Information Delays 80					
7	Representing Decision Processes 83						
	7.1	Experts and Expertise 84					
	7.2	Modeling Decision Processes 87					
	7.3	Weighted-average Decision Models 89					
	7.4	Floating Goals 94					
	7.5	Multiplicative Decision Rule 98					
	7.6	References 99					
8	No	nlinearities					
	8.1	Nonlinear Responses 104					
	8.2	Resource Constraints 109					
9	Ini	tial Conditions					
	9.1	Initializing a Model to Equilibrium 113					
	9.2	Simultaneous Initial Conditions 116					

Preface

These notes provide a quick introduction to system dynamics methods using business examples. The methods of system dynamics are general, but their implementation requires that you use specific computer software. A number of different software packages are available to implement system dynamics, and the Vensim modeling package is used in these notes. This package was selected because i) it supports a compact, but informative, graphical notation, ii) the Vensim equation notation is compact and complete, iii) Vensim provides powerful tools for quickly constructing and analyzing process models, and iv) a version is available free for instructional use over the World Wide Web at http://www.vensim.com. A quick reference and tutorial for Vensim can be downloaded from my system dynamics home page at www.public.asu.edu/~kirkwood/sysdyn/SDRes.htm.

If you obtained this document in electronic form and wish to print it, please note that it is formatted for two-sided printing. The blank pages at the end of some chapters are intentional so that new chapters will start on right-hand pages.

Special thanks to Robert Eberlein for many helpful comments on drafts of these notes.