System Dynamics '90

Edited by
David F. Andersen
George P. Richardson
John D. Sterman

Volume 1: Abbas – Henderson

System Dynamics '90

Volume 1: Abbas – Henderson

Proceedings of the
1990 International System Dynamics Conference

Chestnut Hill, Massachusetts
July 10 through 13, 1990

David F. Andersen
Conference chair

George P. Richardson
John D. Sterman
Program chairs

The System Dynamics Society
Massachusetts Institute of Technology, E40-294
Cambridge, Massachusetts 02139
and
Nelson A. Rockefeller Institute of Government
State University of New York
411 State Street, Albany, NY 12203
Conference Sponsors

ISBN: 0-914341-16-2 (3-volume set)

Preface

In the summer of 1983, a number of scholars gathered at Pine Manor College in Chestnut Hill to discuss current developments in the field of System Dynamics. At that meeting, they voted to create the System Dynamics Society. Seven years later, we return to the same site with a society well in place. The Society has produced six volumes of its journal, the *System Dynamics Review*, and annual research conferences have traveled literally around the world—Brussels, Keystone Colorado, Oslo, Shanghai, San Diego, Stuttgart, and now back to Chestnut Hill.

This conference gives us a chance to reflect on the many advances in the field over the past seven years. A perusal of the subject categories contained in these 1990 Proceedings give an indication of some of the dramatice changes that have taken place, as well as some of the continuing themes:

The subject areas of the 1990 International System Dynamics Conference	
Analysis	Modeling process
Corporate strategy	Negotiation
Corporate structure	Nonlinear dynamics
Decision Making	Organizational learning
Defense & computer information systems	Project management
	Public development
Energy	Public health
Environment	Public management
Group decision support	Simulation games
Learning	Simulation methods
Learning environments	Social services
Macro economics	Sociological studies
Micro economics	State of the field

Consider just four areas: simulation methods, nonlinear dynamics, simulation games, and learning. In 1983, Barry Richmond was writing about enlarging the system dynamics paradigm by creating graduate curricula in enterprise engineering. STELLA was not yet even a gleam in his eye. Richard Day gave us our first conference glimpse of complex nonlinear dynamics, but Erik Mosekilde was writing then about deterministic consequences of stochastic phenomena. Yet to come was his path breaking work on deterministic chaos that led to the special issue of the *System Dynamics Review* and to the Forrester prize he shared on that topic with Javier Aracil. Dennis Meadows had not yet surfaced his interest in simulation games as powerful learning environments. An no paper in the 1983 conference was even using the terms "learning environment" or "systems thinking."

In contrast, more than 20 percent of the presentations at this 1990 conference focus on learning, in either the school or organizational setting. While the field has always focused on modeling to make a difference in the ways people think, there is now a broader conception of what that might mean. Furthermore, there is widespread recognition that modeling to make a difference is a social enterprise that calls for skills and knowledge outside the field of computer simulation. Our literature is widening its scope and its sources, as these papers amply illustrate.

The papers in these Proceedings are arranged alphabetically by first author. Two indices are provided at the back of Volume 3—an author index locating papers of all authors, and a subject index identifying the first author and title of works falling in the subject categories listed above. Plenary sessions can be found as bold headings in the subject index.

All events such as these require the combined efforts of many persons. Dick Nathan and Frank Mauro of the Rockefeller Institute provided their continuing support for a project that had begun before they even arrived. Maria Tudico has excelled in handling the thousands of details that fall upon the Conference Manager. Without her time and effort, this conference simply could not have been. Michael Cooper skillfully assembled the proceedings and met all of the deadlines even when we didn't. Nan Carroll and Liz Praetorious created the administrative system necessary to support this whole affair. Eric Wuestman, Ik Jae Chung, and Sauwekon Ratanawijitrasan provided valuable assistance with conference site logistics.

A large and active conference committee served as the reviewing committee for papers and abstracts and participated fully in the intellectual design of the conference. We especially extend our thanks to Robert Eberlein and Michael Radzicki (Publicity), Nathan Forrester (Conference Events), Janet Gould-Kreutzer (Master Teachers Seminar) Alan Graham (Vendor Displays), and Julie Pugh (Local Arrangements). In addition, valuable insight and help was provided by Jay Forrester, Jack Pugh, Nan Lux, and Peter Gardiner.

David F. Andersen
George P. Richardson
John D. Sterman

Table of Contents

VOLUME 1

Preface xi

A Road Provision Model Using System Dynamics
Khaled A. Abbas 1

The Use of System Dynamics in Modelling Transportation Systems With Respect to New Cities in Egypt
Khaled A. Abbas 16

Issues in Designing Interactive Games Based on System Dynamics Models
David F. Andersen, Ik Jae Chung, George Richardson, Thomas Stewart 31

The Use of System Dynamics to Measure the Value of Information in a Business Firm
Fred Augustine, Jr., Thomas D. Clark, Jr. 46

Dynamics of Food Policy in a Centrally-Planned Economy: The Case of Vietnam
N.L. Bach, J.E. Lukens, Khalid Saeed 61

Simulation of Food Grain Storage Management System in Bangladesh
B.K. Bala, M.A. Satter, Md. Golam Mohiuddin 75

Technical Education Modeling and Simulation
John D. Bernard, D. Henry Pate 90

Simulation as a Tool for Planning of Rural Development Programmes: A Case in Southern Sudan
Tjark Struif Bontkes 105

Contrasting Perspectives on Rationality and the Analysis of Performance Outcomes
Michael G. Bowen 119

Exemplary Computer Model for a Natural History Museum
Charles H. Braden 134

Dynamics of Company Excellence Through Motivation of Employees
Andres E. Breiter 141

Using Complex System Dynamic Models; An Example Concerning the Dutch Dental Health Care System
E.M. Bronkhorst, G.J. Truin, T. Wiersma 155

Improving Education in Public Schools: Innovative Teachers to the Rescue
Gordon S. Brown 164

Anarquia Interfacing Hypermedia and System Dynamics for Urban Management
Antonio Camara, Paula Antunes, Julia Seixas, Lia Vasconcelos 174

Exploring "Ideas", A Multidimensional Dynamic Simulation Approach
Antonio Camara, Francisco Ferreira, Maria Julia Seixas 181

The Cost of Instability in Defense Spending
Rolf Clark 191

End User Computing Growth and Management in Organizations
Thomas D. Clark, Jr., Victoria L. Mitchell, Karen Williams 201

A Model for Future HIV/Aids Incidence in New York City
Catherine Crawford, Fred Wenstop 216

A Behavioral Simulation Model of Single and Iterative Negotiations
Thomas A. Darling, George Richardson . . . 228

Introducing System Dynamics in Schools, the Nordic Experience
Pal I. Davidsen, Margaretha Bjurklo, Hugo Wikstrom . . . 242

A System Dynamics Approach to the Structure and the Economy of Fur Farming and Trade
Pal I. Davidsen, Leif Jarle Asheim . . . 255

Building an Organizational Learning Environment
John P. Davulis, Ulrich Goluke . . . 270

Manager Training Environment for Setting Complex Problems
D.J. de Tombe . . . 280

Negotiating Reality: Using Language and Influence Diagrams to Articulate Knowledge
Julia M. Di Stefano . . . 293

Translating Systems Thinking for People in the World of Business
Linda Dolny . . . 304

The Dynamics of Behavior and Motivation
Gerard Donnadieu, Michel Karsky . . . 319

Regional Energy Planning
Issac Dyner, I.M. Giraldo, A. Lobo, A. Moreno, D. Valencia . . . 333

Casual Tracing: One Technical Solution to the Modeling Dilemma
Robert L. Eberlein, David W. Peterson, William T. Wood . . . 341

Developing a Communication-Oriented Ontology for Using Computer Modeling in Negotiation
John R. Ehrenfeld . . . 355

System Dynamics as a Foundation for Pre-College Education
Jay W. Forrester . . . 367

Policy Design in Oscillating Systems
Douglas Franco . . . 381

An Appraisal of System Dynamics in Assessing the Impact of Computer Information Systems
A. W. Gavine, E. F. Wolstenholme . . . 395

Cognitive Biases, Modeling and Performance: An Experimental Analysis
Nicholas C. Georgantzas . . . 410

A Nonequilibrium, Nonlinear Approach to Organizational Change
Jeffrey Goldstein . . . 425

Freud's Theories in the Light of Far-from-Equilibrium Research
Jeffrey Goldstein . . . 440

Discontinuous Innovation Diffusion Analysis
M. Govindarajan, N. Ramaswamy . . . 455

System Dynamics Combined with Monte Carlo Simulation
Norodd Hagenson . . . 468

The Application of Dynamic Methodology to Assess the Benefit of a Battlefield Information System
Simon M. Henderson, Eric F. Wolstenholme . . . 480

VOLUME 2

Cocaine Use in America: The Evolution of A Dynamic Model
Jack Homer 495

System Dynamics Mapping Applied to Influence Mental Models: A Case Study
Anil B. Jambekar 511

Challenge and Opportunity: The View of Management on the Employment Problem in China
Jiang Xiaodong 522

The Development of System Dynamics in France
Michel Karsky 528

Total Quality and System Dynamics: Complementary Approaches to Organizational Learning
Daniel H. Kim 539

Management Decision Support Simulations for Technology Investment Planning
Thomas Klaue 554

Modeling Complex Economic-Ecological Interactions in the Agricultural Sector in the Netherlands
Onno Knol, Floor M. Brouwer, Marcel W. L. Bovy, Geert O. Nijland,
Pieter Jan M.T. Stallen, Paul J.J. Veenendaal 569

Complex Dynamics in Bacterium-Phage Interactions
Heidi Kristensen, Jacob Engelbrecht, Erik Mosekilde,
Lars Risbo 583

Organizing Home Care in the Future: Using System Dynamics to Assess Organizational Changes
Hans A. Kuipers, Jac A. M. Vennix, Sjoerd Kooiker 596

Simulation Experiments in Corporate Planning for a Steel Plant
Rakesh Kumar 605

Urban Growth Modeling Under the Limitation of Transportation Facilities - Case of Bangkok
Koji Kuroda, T.H. Mark Tsaur 620

Simulation of Interactive Business Strategies and Operations
Ulrich La Roche 635

System Dynamics Analysis as a First Step to Implement Flexible Operation of Manufacturing
Ulrich La Roche 650

On Reliability Improvement of S.D. Model
Li Zhou-Wei 664

The Application of S.D.-I/O/O Model to the Improvement of Regional Industrial Structure and the Economic Development
Li Zhou-Wei, Zhou Yong 673

Designing a Manufacturing Function as a Competitive Weapon Using the Reference Approach
Julio Macedo 686

Economic Policy and Monetary Policy: A System Dynamics Conceptualization
Jose A.D. Machuca 701

Dynamics of Flow of Scientist in Government Research Establishments
Purnendu Mandal, Ashok Jain, Pratap Mohapatra, V.K.C. Sanghi 714

Systems, Science and Schools
Ellen B. Mandinach, Hugh F. Cline 729

System Dynamics in Strategic Planning
Ali N. Mashayekhi 742

A Numerical Sensitivity Analysis of Process Delay in the Incarceration of Juvenile Offenders
Paul E. McCold 754

Time-A Key Factor in Corporate Strategy
Peter M. Milling 769

Modelling the Oil Producers: Capturing Oil Industry Knowledge in a Behavioural Simulation Model
John D. W. Morecroft, Kees A J M van der Heijden 783

System Dynamics and Decisions Under Uncertainty
Erling Moxnes 798

Computer Simulation of Shipbuilding Production Process Management
Ante Munitic, Dusan Ramic, Slavko Simundic, Tonko Bakovic 812

An Analysis of the Cost-Effectiveness of U.S. Energy Policies to Mitigate Global Warming
Roger Naill, Sharon Belanger, Adam Klinger, Eric Petersen 826

A Decision Support System for System Dynamics Modeling
Pei Weimin, Liu Shu-an, Wang Dingwei 841

Designing Learning Environments
Steve Peterson 852

Microstructure and Macrobehavior of Centralized and Decentralized Systems
Jan Polowczyk 863

An Evaluation of Behavioral Simulation Models of OPEC
Stephen G. Powell 878

Building Large System Dynamics Models for Fun & Profit
Anne Quaadgras 893

Pasion: Object-Oriented Simulation on the PC
Stanislaw Raczynski 908

Effects of Stochasticity on an Aggregate Dynamic Model of Commodity Cycles
R. Joel Rahn, Song Yuzhu 918

The Implementation of Welfare Reform Initiatives: A Preliminary System Dynamics Model
Sauwakon Ratanawijitrasin, David F. Andersen, Irene Lurie, George P. Richardson 919

Systems Thinking: A Critical Set of Critical Thinking Skills for the 90's and Beyond
Barry Richmond 934

Teaching Experiments with a Simulation Model of Universal Commodity Production
Alexander L. Ryzhenkov 948

Bringing Practicum to Theory-based Social Science Disciplines: An Illustration with a User-friendly Simulation Laboratory on Issues of Economic Development
Khalid Saeed 963

Is Deterministic Chaos Only a Property of Models?
Khalid Saeed, Nguyen Luong Bach 972

Comments on the Close Similarity Between Indian Population Projections from the Constrained Coalition and Logistic Model and the Census, Government of India and UN Estimates
V.K.C. Sanghi 983

A Dynamic Model to Evaluate Mixed Automobile Fuel Market in Italian Environment
Habib Sedehi, Alessandro Gambaro. Federico Lanza 998

VOLUME 3

Systems Thinking and Organizational Learning: Acting Locally and Thinking Globally in the Organization of the Future
Peter M. Senge, John D. Sterman 1007

Synthetic Policy Design in System Dynamics Models: Some Observations
S.K. Sharma, P.K.J. Mohapatra, M.D. Tyagi 1023

Simulation Model of Japanese Welfare Annuity System
Toshiro Shimada, Saburo Kameyama, Kinya Machida, Akira Uchino, Minoru Watanabe 1038

New Technologies in Simulation Games
Kenneth L. Simons 1047

Application of System Dynamics To an Integrated Economic and Environmental Policy Assessment
William Steinhurst, George Backus 1060

The Spread of '88 Shanghai Type-A Hepatitis: A System Dynamics Model and Analysis
Su Mao-Kang, Wang Huan-Chen 1075

Children's Creative Development Training Program
Orasa Suksawang 1090

Dynamics of Cooperative Development
Orasa Suksawang 1102

System Dynamics Modelling of Group Behaviour: A Conceptual Framework
Sushil and B. John 1117

A Conservation Model for Black Rhino
Johan Swart, Peter Goodman, John W. Hearne 1128

Mode-locking and Chaos in a Periodically Driven Model of the Economic Long Wave
Jesper Skovhus Thomsen, Erik Reimer Larsen, Erik Mosekilde, John D. Sterman 1137

Teaching Theory Building Modeling: Instructional Materials and Software for Theory Building
Robert F. Tinker 1152

Interactive Multicriteria Optimization in System Dynamics Models
M. Toro, J. Aracil, A. Ollero 1164

Some Conceptual Problems in the System Dynamics Models Building Process
Margarita Vazquez, Javier Aracil, Manuel Liz 1175

Eliciting Group Knowledge in a Computer Based Learning Environment
Jac A. M. Vennix, Jan Gubbels, Luc D. Verburgh, Doeke Post 1187

Modeling as Organizational Learning: An Empirical Perspective
Jac A. M. Vennix, Willem J. Scheper 1199

Model-based Analyses of the Dutch Health Care System
Luc D. Verburgh, Jan Gubbels, Doeke Post, Jac A. M. Vennix 1211

A Simulation Support System for Public Education Investment Strategy Analysis
Wang Dingwei, Pei Weiming 1226

Studying Decision Making of Enterprises Under New Circumstances
Wang Qifan, Fu Huimin, Shi Ti 1238

Studying the Impact of Science and Technology on the Economic Growth in a Central City
Wang Qifan, Xiao Chen, Yu Lijuan 1248

Strategy Study on Entire Coordinated Development of China
Wang Qifan, Yu Lijuan 1255

The Study of Dynamical Systems' Nonlinear Characteristic
Wang Qifan, Yao Zhiping 1264

A System Dynamics Model of Socio-Economic Development of Harbin in China
Wang Yanjia 1272

The Application of a Dynamic Methodology to Assess the Benefit of a Logistics Information System in Defence
K.M. Watts, E. F. Wolstenholme 1286

Introduction of System Dynamics in Urban (Regional) Coordinated Development Planning
Wei Hongsen 1299

System Dynamics in Dispute Resolution
Henry Birdseye Weil, Rayford L. Etherton, Jr. 1311

Consensus Building in the Planning Process
Graham W. Winch 1325

On the Very Idea of a System Dynamics Model of Kuhnian Science
Jason Wittenberg 1332

The Design of a Dynamic Model Methodology for the Assessment of Computerised Information Systems
E.F. Wolstenholme, A. Gavine, S. Henderson, K.M. Watts 1346

Modelling Patchy Ecological Systems Using the System Dynamics Approach
Wu Jianguo, Yaman Barlas, John Vankat 1355

Sowing Supply: Compensating Responses by Rural Coca Economies to Intervention in the Cocaine Market
Eric A. Wuestman 1370

System Dynamics Research to China's Inflation
Yan Guangle 1385

A System Dynamics Approach to the Environmental Problems in Taiwan
Yang Jen Shou, Showing H. Young 1392

System Dynamics Simulation for the Management of a College
Zhang Xiaoyong, Mong Guangbin, Yu Zhang 1404

Additional Papers (not indexed):

Generic Computer Tools as Aids in Negotiation: The Issue of User Adoption
J. D. Nyhart, D. K. Smarasan 1417

Negotiation as Discovery and Design
Dhanesh K. Samarasan 1428

Author Index 1443

Subject Index 1447

A Road Provision Model Using System Dynamics

by

Khaled A Abbas
Department of Civil Engineering
University of Newcastle upon Tyne
Newcastle upon Tyne NE1 7RU, U.K.

ABSTRACT

One of the most difficult tasks facing highway administrators is how to efficiently manage the allocation of road funds. In this paper a comprehensible, easy-to-use, highway management tool is presented. This tool takes the form of a computer simulation model which is intended to assist managers of a network of highways to make better decisions concerning the allocation of scarce funds. It mainly simulates the effects of different investment strategies and maintenance options on the road network. This is done by tracing the life-cycle costs of the major activities of providing and maintaining the road system, and by considering the effects that these activities have on the state and performance of the road network.

1. INTRODUCTION

The continued development of the road network is looked upon as a necessity that contributes to the prosperity and wellbeing of a country. Construction, maintenance and upgrading of roads constitute a large portion of the transport budget in many countries, yet the growing conflict between the requirements of the road network and the available financial resources is one of the most serious problems that highway authorities have to deal with. There is a need for simplified planning techniques that are capable of testing alternative strategies for investing in the road network system.

This financial stringency requires the development of road management systems to provide support for highway decision-makers so that they can make more rational, informed decisions. These decisions should be targeted towards achieving a better management and control of the road network system.

Road management systems can be described as computerised, analytic tools that consider the whole life-costing of alternative strategies for the road network. These tools enable the testing of alternative management and planning programmes for the highway sector.

2. PURPOSE AND APPROACH

The main purpose of this study is to construct a dynamic, simulation model that describes the structural, feedback interactions of the road network system. The model is meant to analyse the impacts of proposed changes in the funding levels, as well as in the structure of the priorities involved in the allocation of road funds.

The System Dynamics methodology, (Forrester 1968), is used in this study as the modelling framework within which the road management model is developed.

The model simulates the effects of different road investment strategies. This is done by tracing the life-cycle costs of the activities which are necessary to develop and maintain the road system, and establishing the impacts that these activities have on the condition and performance of the road network. The main objectives of the model are as listed below.

(1) To model the process involved in the allocation of road funds. This allocation process is meant to satisfy, (in a relative sense), the financial requirements of the changing physical condition of the road network. The two main constraints that are considered in this process of allocation include: the level of available funds and the priorities for allocating road funds to the main activities of the road network.
(2) To provide better insight and understanding of the dynamic, feedback nature of the road system.
(3) To act as an experimental management tool for assessing the short- and long-term consequences of different road strategies on the physical development of the road system. A road strategy involves the determination of; road funding levels, priorities for allocating road funds and time intervention criteria for performing maintenance activities.
(4) To assist in management and control of the road system.
(5) To provide a set of performance indicators that describe the state of the road system at any point in its lifetime.

3. MODEL DESCRIPTION

The road provision model consists of two main parts, as shown in Figure 1. The first, is the user interface module, the second is the System Dynamics road provision module, see (Abbas 1990).

In this section, the System Dynamics conceptual model is introduced. The feedback interaction between demand and supply of the road network system is explicitly considered. The main assumptions and some of the important variables of the model are explained. Causal diagrams are considered to be an advanced and comprehensible step of the System Dynamics modelling procedure. This paper presents the fundamental, causal mechanisms underlying the structure of the System Dynamics road provision model.

3.1 Managing the Process of Allocation of Road Funds

Each time interval of the simulation, road funds are allocated among five road system activities. Referring to Figure 2 the main activities of the road provision model include:

(1) road administration activity;
(2) routine road maintenance activity;
(3) road construction activity;
(4) road rehabilitation-reconstruction, i.e. restoration activity; and
(5) periodic road maintenance activity.

This investment allocation process is performed in a dynamic fashion so as to be relatively consistent with the competing priorities and the changing demands of the road network system. The priorities for the allocation of road funds are set by the modeller to be in accordance with the most commonly practised management of road funds in developing regions. The priorities are as shown in Table 1.

Table 1: Priorities for Allocation of Road Funds

The Road Network Funds	Priority
Road Administration Funds	1
Routine Road Maintenance Funds	2
Road Construction Funds (***)	3
Road Rehabilitation-Reconstruction Funds (***)	3
Periodic Road Maintenance Funds	5

(***) Both construction and restoration of roads have the same priority regarding the allocation of road funds. This assumption is based on the fact that both construction and restoration of roads will eventually lead to kilometres of roads starting new life cycles. Absolute allocation is determined using allocation factors. These factors are computed according to the financial demand of the road construction activiy versus that of the road restoration activity.

The stated structure, describing the priorities, considered in the allocation of road funds may be varied to test the effects on road network performance of alternative priorities for the allocation of road funds.

3.2 Main Assumptions and Definitions of the Model

In this section of the paper, the reader is advised to refer to the causal diagrams describing the structure of the model and presented throughout Figures 2 to 9. This section is meant to explain the main implicit assumptions and definitions of the System Dynamics road provision model.

- Total Permitted Road Kilometres, (refer to Figure 5), is a parameter that explicitly caters for the constraint of land use planning, taking into account the following constants:

    - maximum land area of the region;
    - maximum allowed ratio of road area to land area; and
    - average road width.

    The constants are exogenously specified by the model user. On the other hand, it is to be noted that another System Dynamics model is currently under development which is expected to explicitly model the dynamics of demand for road cosntruction.

- Recent field surveys, supplemented by the judgement of engineers of the World Bank, suggest it is possible to distribute a country's roads among three classes of condition: good, fair, and poor. A road in good condition requires only routine maintenance to remain that way. A road in fair condition needs resurfacing , i.e. periodic maintenance. A road in poor condition has deteriorated to the point that it requires either partial or full reconstruction, i.e. restoration. (Harral 1988)

- Good To Fair Road Kilometres Rate, (refer to Figures 7 & 8), is the rate that dynamically determines the number of kilometres of roads degrading from good to fair condition, over the incremental time intervals of the simulation. Periodic road maintenance of a road is considered necessary once the road condition degrades from good to fair. It is vital to perform the periodic maintenance on time. Periodic maintenance certainly betters the existing condition of a road and prolongs its life-cycle. There are different views pertaining to the exact extent of this betterment, but discussion of these views is outside the scope of this paper.

- Fair To Poor Road Kilometres Rate, (refer to Figures 6 & 8), is the rate that dynamically determines the number of kilometres of roads degrading from fair to poor condition, over the incremental time intervals of the simulation. Restoration of a road is considered necessary once the road condition falls from fair to poor. Once restorated, the road kilometres restart a new life-cycle.

- Good-Fair Condition Road Kilometres: Level, (refer to Figures 4 & 8), represents the accumulation of road kilometres, which are in a good or fair condition, over time, and hence requiring annual routine maintenace.

- To avoid double counting in the maintenance activities, Periodic Road Maintenance Rate is subtracted from the Routine Road Maintenance Rate. This avoids performing routine maintenance to road kilometres, which are already expected to be periodically maintained, (refer to Figure 4).

- Evaluation of different road strategies is mainly carried out by comparing the output of the model which is mainly in the form of performance indicators, against the user criteria. Some of the main road performance indicators produced by the model are listed below.

(1) Number of Kilometres of roads in:
   (a) good condition;
   (b) fair condition; and
   (c) poor condition.

(2) Efficiency and deficiency indices of:
   (a) administration of roads;
   (b) construction of roads;
   (c) routine maintenance of roads;

(d) restoration of roads; and
(e) periodic maintenance of roads.

(3) Expenditure and levels of:
(a) constructed roads;
(b) administered roads;
(c) routinely maintained roads;
(d) restorated roads; and
(e) periodically maintained roads.

3.3 Main Input Values by the Model User

The user interface module can be described as a computerised, friendly dialogue, designed mainly to instigate creativity in constructing alternative scenarios for the road network, and also to work as a medium to facilitate the specifiction of the model exogenous parameters by the user. The following presents the main input parameters of the model and describes the options available to represent these parameters, through using the user interface module.

- Initial unit cost of:

  (1) Yearly Road Administration Cost Per Kilometre.
  (2) Routine Road Maintenance Cost Per Kilometre.
  (3) Periodic Road Maintenance Cost Per Kilometre.
  (4) Road Construction Cost Per Kilometre.
  (5) Road Rehabilitation-Reconstruction Cost Per Kilometre. (Refer to Figure 10)

- Inflation/deflation rates of the previously stated unit costs. (Refer to Figure 10)

- The user can choose from among several forms that are available for inputing road funds. Road Funds can be generated using any of the following options:

  (1) Empirical function (linear or nonlinear).
  (2) Deterministic function.
  (3) Random Stochastic function (stochasticity assumed to be of the Gaussian type, and randomness is based on the pseudo randomisation process).
  (4) Combination of any of the above i.e. at a time specified by the user, the function of the road funds changes from one form to another. The available combinations include:
  (a) Empirical function with Deterministic function.
  (b) Empirical function with Stochastic function.
  (c) Deterministic function with Stochastic function.

- The life cycle of a road progresses through time from an initial state of being in good condition, passing through a state of fair condition and terminating at a state of poor condition, where the road is almost unusable, due to radical structure failure, i.e. high surface roughness values. The maintenance specifications of the model matches particular