

A CASE STUDY IN PROBLEM DEFINITIONFOR A SYSTEM DYNAMICS MODEL

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SUMMARYIntroduction

This paper contributes to the discussion of academic training requirements for System Dynamics modellers. In particular, it suggests that training in Strategic Management can provide the System Dynamics modeller with some essential complementary tools and a "top management perspective" (or systems viewpoint), which is needed to define problems of real managerial interest.

To illustrate these points, the author describes his experiences in defining a problem for system dynamics modelling. The future prospects for the New Zealand Forestry Sector, and the New Zealand Forest Service, in particular, are described and the problem for modelling is presented.

Strategic Management

Strategic Management is the responsibility of top management, and is a continuous process which can help an organisation adapt to a constantly changing external environment. Strategic Management training can help provide a "top management perspective" of all the functional parts of an organisation, e.g. finance, marketing, production, etc., and is, therefore, an extremely useful aid in helping to define problems of real managerial

interest. The strategic management process includes the following elements:

1. Setting the organisation's objectives.
2. Internal analysis, which involves assessing the strengths and weaknesses of the organisation.
3. External analysis, which involves appraising the potential threats and opportunities from the external environment.
4. Consideration of alternative strategies.
5. Choice of the most appropriate strategy.
6. Implementation of the strategy.
7. Evaluation of the strategy.

Both the strategic management process and the system dynamics method are concerned with guiding an organisation (system) through time in the face of threats and opportunities from a rapidly changing external environment. It is suggested that the two methods complement each other as follows:

- (a) Stages 1-3 of the strategic management process described above, i.e. setting objectives, internal analysis and external analysis, can provide the System Dynamics modeller with a systematic approach to defining problems of real managerial interest, and help in defining the model boundaries.
- (b) A system dynamics model can be most useful in stages 4-7 of the strategic management process, i.e. considering alternative strategies, choosing, implementing and evaluating the strategy. A system dynamics model can be used to explore more systematically the interrelationships between the organisation and its external environment. In particular, a system dynamics model is a very powerful aid in helping to examine the implications of alternative

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strategies, and in helping to design robust policies and an improved organisational structure, which can help steer the organisation towards meeting its objectives.

#### Background to the Problem

Substantial changes could occur in the New Zealand Forestry Sector over the next 30 - 40 years, as a result of the development of vast areas of new plantations in exotic forests (i.e. species not native to New Zealand) since 1960. Potential exotic roundwood removals are expected to remain at the present level of about 9 million cubic metres per annum throughout the 1980s. From 1990 onwards, the potential exotic roundwood supplies are expected to increase quite sharply to reach a level of about 18 million cubic metres per annum by the late 1990s. If new plantings are continued as planned, then the potential exotic roundwood supplies could reach a level of about 36 million cubic metres per annum by the year 2015.

In 1978 approximately 45 percent (or 4.1 million cubic metres) of the wood removed from New Zealand's forests was exported in various processed forms, e.g. logs, sawn timber, pulp and paper. Unless some new large scale industry such as energy production is developed, virtually all of the increase in the exotic wood supplies during the 1990s will be available for export. Thus approximately 12 million cubic metres per annum could be available for export by the late 1990s, approximately three times the present level (and possibly 28 million m<sup>3</sup> p.a. by 2015, or seven times the present level).

The New Zealand Forest Service administers (for the State) 57 percent of the exotic forests and 61 percent of the indigenous forests in New Zealand. The Forest Service employs approximately 8000 people, plus a further 800 people on the Government's special programme for the unemployed. In 1979-80, N.Z.\$159.5 million was voted to the Forest Service, most of this

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being spent on sawmilling. Revenue was N.Z.\$70 million. The N.Z. Forest Service has 4 operating functions, which are: environmental forestry, forestry research, production forestry and sawmilling operations.

#### Definition of the Problem

Before commencing research for a PhD at the University of Bradford, the author had been employed as an economist/statistician with the N.Z. Forest Service. The question the author had intended to investigate by developing a system dynamics model, was: "What are the future market prospects for New Zealand's exports of forest products?". This type of question, i.e. a predictive question not particularly suitable for system dynamics modelling, reflected the author's academic training in econometrics and mathematical techniques, and his functional position in the N.Z. Forest Service. It was also a fairly obvious question, considering the potentially huge increases in exotic roundwood that could be available for export from 1990 onwards.

However, after completing a case study course, at Bradford, in Strategic Management (while receiving training in System Dynamics), the author's perspective shifted from a functional perspective to a top management perspective (or systems viewpoint) of the organisation.

With this perspective the author examined the strengths and weaknesses of the N.Z. Forest Service, and the potential threats and opportunities from its external environment to define a problem for modelling. Recent reports had emphasised the weaknesses in financial management and long term planning in the N.Z. Forest Service. With the prospects of double the present level of exotic roundwood supplies by the turn of the century, and possibly a further doubling by the year 2015, the author identified strategic planning as the most important problem area for modelling. Consequently, the author is now developing a System Dynamics model to help investigate the following question: "What resources and policies, e.g. financial, new planting, silvicultural, harvesting, personnel, etc., are needed to meet the long term objectives of the N.Z. Forest Service for its exotic production forests?"

A Case Study in Problem Definition for a  
System Dynamics Model

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Abstract

This paper contributes to the discussion of academic training requirements for System Dynamics modellers. In particular, it suggests that training in Strategic Management can provide the System Dynamics modeller with some essential complementary tools and a top management perspective (or systems viewpoint), which is needed to define problems of real managerial interest.

To illustrate these points the author discusses his experiences in defining a problem for system dynamics modelling. The future prospects for the New Zealand Forestry Sector, and the New Zealand Forest Service, in particular, are described, and the problem for modelling is presented.

<sup>1</sup> The views presented in this paper are the personal views of the author and do not represent the views of the Bradford System Dynamics Research Group or the New Zealand Forest Service.

## Introduction

This paper is a contribution to the discussion instigated by W.Fey (1981) at to why System Dynamics has not been more widely accepted and successful, even though it has had nearly 25 years to become established. (J.W.Forrester started the Industrial Dynamics Group at M.I.T. in 1956).

In the related field of Corporate Planning, Naylor (1979) suggests that one of the major reasons for the limited success of Corporate Planning is inappropriate academic training:

"If management scientists spent 20 percent less time solving differential equations and inverting matrices during their academic careers, and 20 percent more time learning how to define problems and interact with management, corporate modelling would take a great forward leap."

Perhaps inappropriate academic training is also one of the major factors restricting the success of System Dynamics. It is suggested in this paper that training in Strategic Management can provide the System Dynamics modeller with some essential complementary tools and the perspective needed to define problems of real managerial interest.

To illustrate these points an anecdotal case study in problem definition for a system dynamics model is presented. This is based on the future prospects for the New Zealand Forestry Sector and the New Zealand Forest Service, for whom the author works.

## Strategic Management

Strategic Management is the responsibility of top management, and is a continuous process which can help an organisation adapt to a constantly changing external environment. It is defined by Glueck (1980) as:

"Strategic management is that set of decisions and actions which leads to the development of an effective strategy or strategies to help achieve corporate objectives."

Strategic Management training can help provide a 'top management perspective' (or systems viewpoint) of all the functional parts of an organisation, e.g. finance, marketing, production, computer services, etc., and is, therefore, an extremely useful aid in helping to define problems of real managerial interest. Glueck (1980) suggests that:

"Strategic management helps educate managers to become better decision makers. It helps examine the basic problems of a company."

The strategic management process, (based on Glueck, 1980) includes the following elements:

1. Setting the organisation's objectives.
2. Internal analysis - assessing the strengths and weaknesses of the organisation by systematically examining the following broad areas: internal political structure, organisational structure, present strategies and policies, finance, accounting, marketing, distribution, production, operations, research and development, personnel, labour relations, resources and assets.
3. External analysis - systematically appraising the potential threats and opportunities from the external environment. This requires consideration of the following general areas: factor inputs, product markets, competitors, technological environment, social environment, political and legal environment, and geographic environment.
4. Consideration of alternative strategies - the generation of a number of alternative strategies as a result of matching the environmental threats and opportunities identified by the external analysis, with the organisation's strengths and weaknesses identified by the internal analysis.
5. Choice of the most appropriate strategy - the choice of the strategy which will best meet the organisation's objectives. This choice involves consideration of selection factors, evaluation of alternatives against these criteria, and the actual choice.

6. Implementation of the strategy - the assignment of managers to match the strategy, development of functional policies and the organisational structure to support the strategy.
7. Evaluation of the strategy - the determination of whether the strategic choice as implemented is meeting the objectives of the enterprise.

Both the strategic management process and the system dynamics method are concerned with guiding an organisation (system) through time in the face of threats and opportunities from a rapidly changing external environment. It can be shown that the two methods complement each other as follows:

- (a) Stages 1 - 3 of the strategic management process described above, i.e. setting objectives, internal analysis and external analysis, can provide the System Dynamics modeller with a systematic approach to defining problems of real managerial interest, and help in defining the model boundaries.
- (b) A system dynamics model can be most useful in stages 4 - 7 of the strategic management process, i.e. considering alternative strategies, choosing, implementing and evaluating the strategy. A system dynamics model can be used to explore more systematically the interrelationships between the organisation and its external environment. In particular, a system dynamics model is a very powerful aid in helping to examine the implications of alternative strategies, and in helping to design robust policies and an improved organisational structure, which can help steer the organisation towards meeting its objectives.

Drucker (1977) comments on the importance of quantitative analysis:

"Most managers know that they need better tools. Most have learned through bitter experience that intuition is unreliable, if not downright treacherous, if used as the only basis for decision.

Indeed, most managers have long suspected what a leading management scientist of today, Jay W. Forrester of M.I.T. brilliantly demonstrated: complex systems actually behave 'counter-intuitively'; the course of action suggested by common sense tends to be wrong. And markets, technologies, and business are very complex systems indeed".

### The Case Study

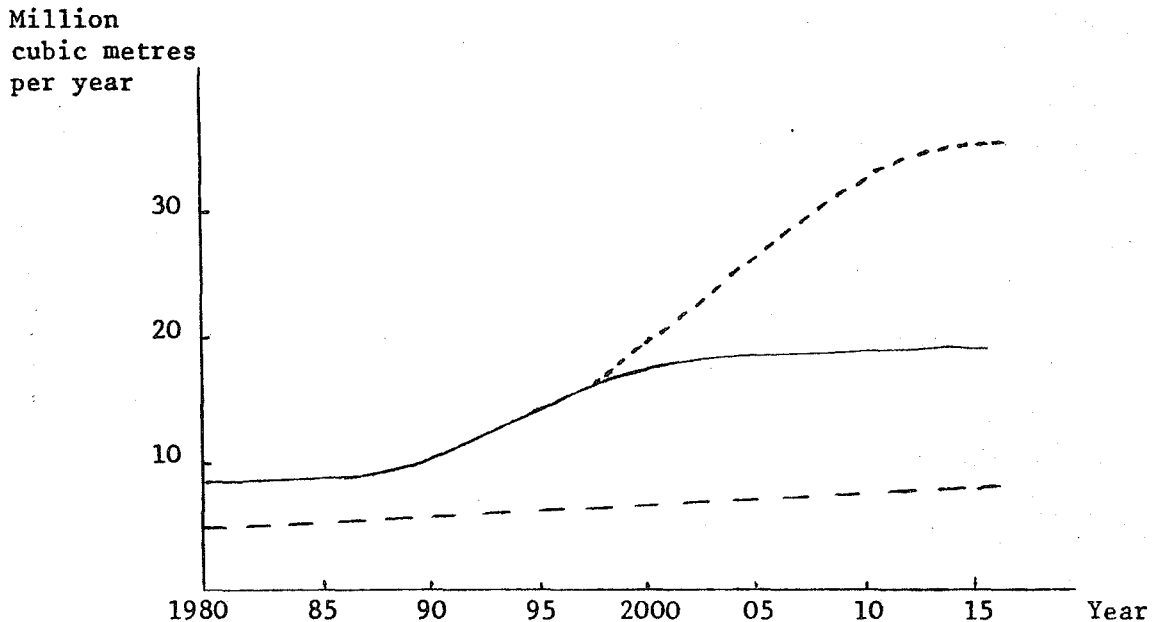
The future prospects for the New Zealand Forestry Sector are provided as background for the problem the author is investigating, with the aid of a system dynamics model. This is followed by a brief discussion of the functions of the New Zealand Forest Service. The organisational chart of the New Zealand Forest Service is provided to illustrate some of the ideas presented in the discussion on strategic management. Finally the problem for system dynamics modelling is presented.

### Background to the Problem

Substantial changes could occur in the New Zealand Forestry Sector over the next 30 - 40 years, as a result of the development of vast areas of new plantations in exotic forests (i.e. species not native to New Zealand) since 1960. Potential exotic roundwood removals are expected to remain at the present level of about 9 million cubic metres per annum throughout the 1980s. From 1990 onwards, the potential exotic roundwood supplies are expected to increase quite sharply to reach a level of about 18 million cubic metres per annum by the late 1990s. If new plantings are continued as planned, then the potential exotic roundwood supplies could reach a level of about 36 million cubic metres per annum by the year 2015. This is shown in Figure 1 below.

Figure 1.

New Zealand's Potential Exotic Roundwood Supplies  
and Projected Domestic Consumption



Key: — potential roundwood supplies based on a 30 year rotation  
 ---- potential roundwood supplies if new planting is continued as planned  
 - - - projected domestic consumption of forest products. (roundwood equivalent)

Sources: based on Levack (1979) and New Zealand Forest Service (1978)

In system dynamics terms this is equivalent to a 10 - 20 year period of a sustained and large ramp input. Therefore the forestry system will encounter a severe exogenous input.

In 1978 approximately 45 percent (or 4.1 million cubic metres) of the wood removed from New Zealand's forests was exported in various processed forms, e.g. logs, sawn timber, pulp and paper. Unless some new large scale industry such as energy production is developed, virtually all of the increase in the



exotic wood supplies during the 1990s will be available for export. Thus approximately 12 million cubic metres per year could be available for export by the late 1990s, approximately three times the present level (and possibly 28 million m<sup>3</sup> p.a. by 2015 or seven times the present level).

### New Zealand Forest Service

The New Zealand Forest Service administers (for the State) 57 percent of the exotic forests and 61 percent of the indigenous forests in New Zealand. The Forest Service employs approximately 8000 people, plus a further 800 people on the Government's special unemployment programme. In 1979-80, N.Z.\$ 159.5 million was voted to the Forest Service, most of this being spent on the production forests, with N.Z.\$ 28 million being spent on sawmilling. Revenue was N.Z.\$ 70 million. (Public Expenditure Committee, 1980).

The N.Z. Forest Service has four operating functions. These are:

#### Social Functions -

- (a) Environmental Forestry - including soil protection, water regulation, flora and fauna preservation, and provision of recreational activities.
- (b) Research - a wide range of forestry research activities.

#### Trading Functions -

- (c) Production Forestry - the Forest Service produces over half the indigenous and exotic wood in New Zealand. Of the Forest Service sales in 1979, 27 percent was exported and the balance sold locally. Currently the N.Z. Forest Service removals of exotic timber are approximately 5 million cubic metres per year. This is expected to double to about 10 million cubic metres per year by the late 1990s. If new planting is continued as planned, this could further double to about 20 million cubic metres per year by the year 2015. (Levack, 1979).
- (d) Sawmilling Operations - The Commercial Division operates two sawmills which produce approximately one tenth of the New Zealand sawmilling industry's rough sawn timber.

### Perspective

Before commencing research for a PhD at the University of Bradford, the author had been employed as an economist/statistician with the New Zealand Forest Service. His position and perspective is represented by the point ① on the organisational chart of the N.Z. Forest Service, shown in Figure 2 below. The question the author had intended to investigate by developing a system dynamics model, was:

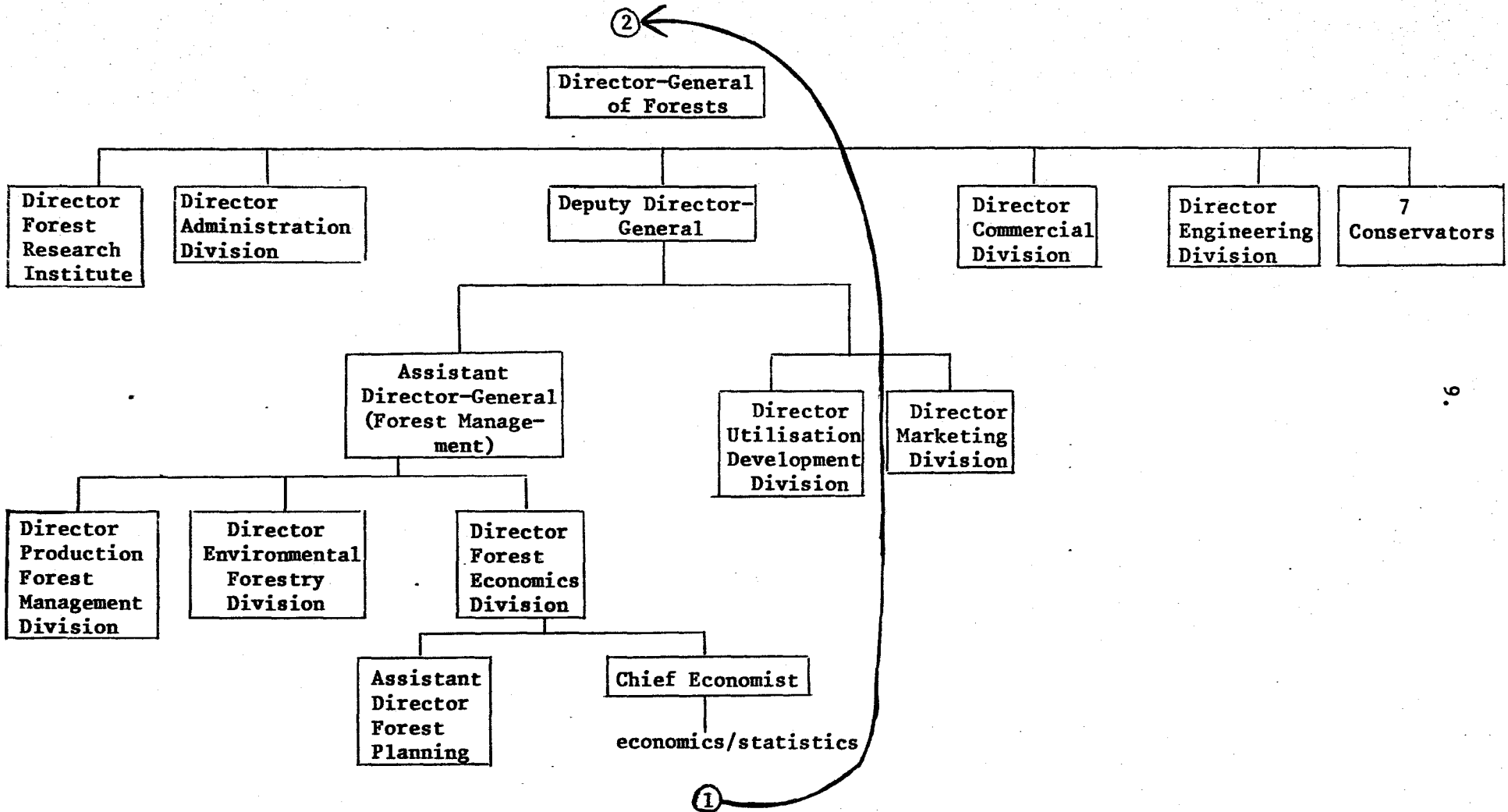
"What are the future market prospects for New Zealand's exports of forest products?"

This type of question, i.e. a predictive question not particularly suitable for system dynamics modelling, reflected the author's academic training in econometrics and mathematical techniques, and his functional position in the New Zealand Forest Service. It was also a fairly obvious question, considering the potentially huge increases in exotic roundwood that could be available for export from 1990 onwards.

However, after completing a case study course, at Bradford, in Strategic Management (while receiving training in System Dynamics), the author's perspective altered to the position represented by the point ② in Figure 2, i.e. a top management perspective (or systems viewpoint) of the organisation. It is suggested, by the author, that this is the "perspective" needed to examine and define problems of real managerial interest for System Dynamics modelling, and that training in System Dynamics is not complete without this perspective.

Figure 2

Organisational Structure of the New Zealand Forest Service



Key: ① - represents the author's 'perspective' and position while working in the New Zealand Forest Service  
② - represents the 'perspective' (or systems viewpoint) needed to define problems for system dynamics modelling (or any strategic analysis).

Source: based on New Zealand Forest Service (1979)

### Definition of the Problem

With the top management perspective and skills gained from a study of strategic management, the author examined the strengths and weaknesses of the New Zealand Forest Service, and the potential threats and weaknesses from its external environment, to define a problem for modelling. Recent reports by the Development Finance Corporation of New Zealand (1980), and the Public Expenditure Committee (1980), had emphasized the weaknesses in financial management and long term planning in the New Zealand Forest Service. With the prospects of double the present level of exotic roundwood supplies by the turn of the century, and possibly a further doubling by the year 2015, the author identified strategic planning as the most important problem area for modelling.

Consequently, the author is now developing a System Dynamics model to help investigate the following question:

"What resources and policies, e.g. financial, new planting, silvicultural, marketing, harvesting, personnel, etc., are needed to meet the long term objectives of the New Zealand Forest Service for its exotic production forests?"

In fact, it was for this type of managerial problem that System Dynamics was first developed by Forrester (1961) and further developed by Coyle (1977).

### Summary

This paper has presented a contribution to the discussion of what academic training is necessary for a System Dynamics modeller. It was suggested that training in Strategic Management can provide the System Dynamics modeller with some essential complementary tools and a "top management perspective" (or systems viewpoint), which is needed to define problems of real managerial interest. This training is stressed however, because apart from being taught in Management Departments, System Dynamics is also taught in other academic departments, e.g. Engineering, Applied Mathematics, and Economics, where courses in Strategic Management may not be readily available.

To illustrate these points the author described his experiences in defining a problem for system dynamics modelling. The future prospects of the New Zealand Forestry Sector and the New Zealand Forest Service, in particular, were described, and the problem for modelling was presented.

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References

- Coyle, R.G. Management System Dynamics, John Wiley & Sons Ltd., 1977
- Development Finance Corporation of New Zealand Forest Industry Study, Development Finance Corporation of New Zealand, 1980.
- Drucker, P.F. Management, Pan Books Ltd., 1977.
- Fey, W. Public Communication re the 1981 System Dynamics Conference, School of Industrial and Systems Engineering, Georgia, January, 1981.
- Glueck, W.F. Business Policy and Strategic Management, Third Edition, McGraw-Hill Kogakusha, Ltd., 1980.
- Levack, H.H. Future National Wood Supply, New Zealand Journal of Forestry, Vol.24, No.2, 1979, pp. 159-71.
- Naylor, T.H. Corporate Planning Models, Addison-Wesley Publishing Co.Inc 1979.
- New Zealand Forest Service Statistics of the Forests and Forest Industries of New Zealand to 1977, (and updates), Government Printer, Wellington,N.Z., 1978.
- New Zealand Forest Service New Zealand Forest Service - Functions and Divisions, Unpublished Report, N.Z.Forest Service, 1979.
- Public Expenditure Committee Financial Management in the Forest Service and Financial Management in the Education System, Government Printer, Wellington, New Zealand, First Report, 1980.