Available online at www.sciencedirect.com
ScienceDirect
International Journal of Project Management 29 (2011) 696 – 705
International Journal of Project Management
www.elsevier.com/locate/ijproman

A control system project development model derived from System Dynamics

A.S. White *

School of Engineering and Information Sciences, Middlesex University, The Burroughs, Hendon, London NW4 4BT, United Kingdom

Received 30 March 2010; received in revised form 18 June 2010; accepted 27 July 2010

Abstract

This paper examines established Systems Dynamics (SD) models of projects in order to simplify them. These models are highly non-linear and contain large numbers of variables, with built in decisions using empirical data. A SIMULINK version of an SD model was created and conclusions are made with respect to the main controlling factors, compared to a NASA project. Stages in simplification are described leading to a control system model. This model is then used to develop criteria to judge stability, controllability and observability of projects with use for practical decisions by project managers. All the models and the NASA data are compared to allow the reader to judge the efficacy of the simulation. The developed model is then compared with another project solution.

Keywords: Project development; Reduced model; Minimal project model; System dynamics; Control system analysis

1. Introduction

Newspapers in the UK are continually reporting project failures from construction to military projects to IT. Software projects in particular have a poor success rate for reliability, meeting due dates and completing to budget (Smith, 2002; Yeo, 2002; RAE, 2004; Ahsan and Gunawan, 2010). Successful project management (Abdel-Hamid and Madnick, 1989) is related to technical production processes, time scheduling in a dynamic environment, individual differences in project managers, members and team processes. Capers Jones (1996) has estimated that such IT projects only have a success rate of 65%. The cost of such disasters such as the UK National Air Traffic System, UK Health Service IT systems and the London Ambulance Service computerisation is high in both human terms and money.

Projects may be considered as a system in which demands are made (the requirements) and an internal project organisation, which is controlled to produce the software goals, while being disturbed by the external environment.

Significant progress has been made in the use of System Dynamics methods to describe the operation of software and other projects (Rodrigues and Bowers, 1996a,b). Lin and Levary (1989) describe computer aided software design using System Dynamics, expert systems and a Knowledge based management system used in the design of a space station. More recently Häberlein (2004) has discussed the common structures involved in SD models. Rodrigues and Bowers (1996a,b) have established the role of System Dynamics in project management and Madachy (2007) has recently produced a benchmark book explaining and detailing the used of SD methods in software projects.

The models of operation of the software development process were described by the successful System Dynamics (SD) models of Abdel-Hamid and Madnick (TAH) (1991), which set up equations relating levels(states) such as the *number of reworked errors* and relates them to rates such as *the error detection rate* or *the rework rate.* The TAH model was validated against NASA data for a satellite project and the agreement is very good. The SD model structure is highly non-linear with a number of theoretical assumptions, for example about how the errors in the coding are

* Tel.: +44 2084115411; fax: +44 2084116943.
E-mail address: a.white@mdx.ac.uk.

0263-7863/$ - see front matter
doi:10.1016/j.ijproman.2010.07.009

propagated. These structural assumptions do not allow for System Dynamics models to be used to develop any general rules to allow managers to make sound judgements based on good analysis. The comparison with models of inventory processes, which are related, is the rationale for this research programme. SD inventory models developed by Forrester (1961) were non-linear and contained a number of factors, such as employment rate, that made the problem too complex for simple rules to be developed. Disney and Towill at Cardiff (2002) and others devised linear control system models to enable operational rules to be investigated and optimal solutions to be found as well as stability margins to be obtained (White and Censlive, 2006). Simplification of the project development model is being tackled in the USA with control system models of software testing (Cangussu et al., 2002) and in the UK by linearising the SD model (White, 2007a). The whole purpose of this research is to develop simple control system models of the project development process, as in inventory analysis, and obtain rules for stability. This must include all the models of software development including the evolutionary project management methods of Gilb (2005) and iterative methods such as SCRUM and RAD.

The advantages of such control analysis is to enable rules to be created for stability, controllability and observability to be used by project managers in the same way they can used scheduling and decision theory. They will also allow greater accuracy in prediction of projects at an early stage in the development process, in particular when to change the workforce for maximum efficiency.

In order to succeed the project manager must have a mental model of how the system operates to achieve the system goals. It is also important to realise that no matter how successful we are at controlling the external disturbances, the goal of a successful project cannot be achieved if the internal processes are not stable. This is only possible if a good internal model is available and the best model basis extant is that of Abdel-Hamid. However to use this model requires a large amount of empirical data, most of which is not available *ab initio.*

The purpose of this paper is to set out an analysis of the system dynamics model from a control engineering point of view illustrating how the initial state of the system is at best neutrally stable. It will show how the reduced system is also unstable. This is a consequence of major variables *CUMSD* and *CRPRG* increasing, of necessity, steadily with time.

2. System Dynamics models

The model created by Tarek Abdel-Hamid (TAH) consists of four main subsystems (his terminology) (Fig. 1).

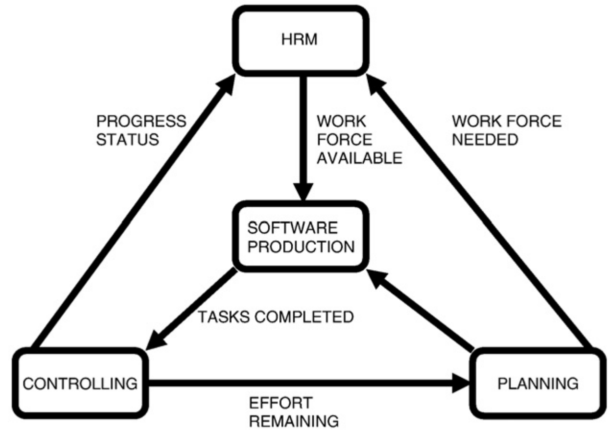

Fig. 1. Software development subsystems (from Abdel-Hamid).

The main functions set up in the model are an input block supplying information such as the size of the task, the estimate of the size etc. The blocks are Human Resource management, Production, Planning and control subsystems. Each of these has sub-subsystem blocks for example the production sub-system has the Manpower Allocation System (MAS), the Software Development System(SDS), the Software Testing System (STS) and the Quality Assurance System (QAS). Each subsystem has individual components with decisions built in as a representation of how management decisions were made.

2.1. Validation of the model

Data from a NASA project with 24.4 K DSI was used by Abdel-Hamed with quite good information and a very good degree of agreement. The model has the flexibility to add in overtime at a particular stage of the project to see what effect this has on overall completion date and cost.

The SIMULINK implementation of the SD model not gives only good agreement with the original Dynamo model but also agrees with the observed data despite using slightly different implementation of some decisions. This difference in these two sets of data is that the NASA data includes an amount of overtime, not available in detail. The NASA data lies between the simulated values of zero and full overtime.

The major dominating eigenvalues depend on the hiring delay, the assimilation delay and the time of employment. This means that the whole trajectory of the project is dominated by the HR policies of the company.

Non-linearity is apparent when convoluted decisions are incorporated in the model. This is quite typical of SD models in general. It is therefore difficult to predict stability in these models, even sensitivity simulation is difficult since small changes in parameters produce large variations in output behaviour and the following analysis is a first step in trying to achieve such insights. It is also the case that if the completion time predicted by the SD model is put back in as one of the initial trial values then the new completion time is not the same as originally predicted. This is also true of the other values that are initially guessed such as the size of the software. This is a result we might expect from such a nonlinear model. Although the model is validated using public data available, it is known that several larger projects have been validated using private company data by the System Dynamics software vendors. Although there are internal feedback loops the TAH system is not a closed loop control system since there is no target value to aim for and no error correction.