System Dynamics Model of the Standards Development Process

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Abstract

A overall dynamic model of the standards development process was developed to document savings potentially obtainable from standards improvements in the Defense Information System. The model will aid in allocating standards development resources. Different funding and personnel strategies are quantitatively compared.

System Dynamics Model of the Standards Development Process

Overview

An overall dynamic model of the standards development process was developed to document savings potentially obtainable from standards improvements in the Defense Information System (DIS). DIS is defined as the aggregation of all DOD information systems, including sensors, data entry devices, displays, communications networks, and computer resources. The model provides a 20-year view of the application of standards to DIS programs. Quantitative measures of performance are calculated and standards resource allocation is optimized.

Introduction

The standards development process may be described in terms of many interacting factors with nonlinear feedbacks. Sheer intuitive judgement is unreliable about how the total process will change with time, even when there is good knowledge of the individual parts of the system. Standards lifetimes can be 20 years or more. Similarly the time to identify potential standards projects and complete the standard can take years. Thus, a long-range perspective is required. The system dynamics model encodes the underlying standards process in an easily understood structure. Quantitative measures of performance are provided to defend standards budgets, document savings, and guide resource allocation. These include standards coverage, proportion of potential savings achieved, total dollars saved, and standards costs. Alternative implementation strategies are evaluated and optimal personnel strategies are developed. The effect of standard budget variation on standards process performance is quantitatively evaluated. Sensitive policy parameters are identified including: labor productivity, relative workload, relative wage rate, and training. The model can be extended to monitor existing standards activities and standards estimates.

Model Implementation

The model was implemented in the Stella systems dynamics simulation language on an Apple Macintosh computer. Stella is easy to learn, provides animated graphics, interfaces to spreadsheets and object oriented graphics programs. Stella also provides a direct interface to Apple Hypercard. This was used to develop an animated teaching game from the model . Figure 1 is a diagram of the complete model. Conserved flows such as projects, dollars, or people are shown with double lines (pipes). Information flows are shown with single lines. Information flows are instantaneous while conserved flows take time to change. Levels or stocks are shown as rectangles. The shading indicates the relative amount of stock at that point in time. Valves (circles with a T) indicate rates of flow into or out of a level. The position of the arrow within the circle indicates the relative rate of conserved flow. Auxiliary values used in calculating rates or measures are shown with circles.

The model is divided into three sections: projects, savings, and personnel. These are named by the conserved flow represented. The projects and savings sections each have five levels. Project levels are: potential, identified, standards, obsolete, and lost. The potential projects level represents the number of potential DIS standards projects. This value is estimated based on the success of the identification effort. New projects enter this level at the technology growth rate (TGR). The identification task consists of a description of the standard project, estimate of annual standard savings, standard life, and staff months to write the standard. Projects are identified at the identification rate (IDR) which is dependent on the number of personnel assigned (PER_ID) and labor productivity (ID_P_PER). Identified projects join the identified level (ID_PROJ). They are ranked in savings times standard life divided by writing cost order. The most cost effective projects are chosen for writing and join the standards level (STDS) at the writing rate (WR). Writing rate is dependent on personnel assigned and labor productivity. Completed standards join the obsolete standards level (OBS_STDS) at the obsolescence rate (OBS_S). Projects are lost (join the PROJ_LOST level) while awaiting identification and writing based on the standard project life. The model calculates identification coverage and standards coverage performance measures.

The savings section just below the projects section has similar levels except now the conserved flow is dollar savings. Beta distributions of standard project life and cost were fit based on initial efforts at identifying projects and writing standards. Since the most cost effective identified projects are first selected for writing, cost effectiveness would decrease through time if there was no growth in technology. Initially most personnel are allocated to the identification task, so there is a wide range of identified projects to choose from. Later more personnel are allocated to the standards writing and approval process. Some personnel remain in the identification task to handle the technological growth rate. Once a standard is written and accepted, annual savings are available for the rest of its life. The savings remaining (SAV_REM) level includes all these savings. As time progresses a proportion of these savings (SAV_P_YR rate) are taken and join the savings taken (SAV_TAKEN) level. Note that if all standards efforts ceased, savings in the savings remaining level will still be taken. Cost effectiveness is the savings taken per year divided by the annual standards budget. Savings proportion is the total savings taken and remaining divided by the potential savings (savings in all the savings levels). With infinite personnel or labor productivity, all potential projects would instantaneously be identified and written and no projects would be lost while waiting. This would result in a unity savings proportion.

The bottom personnel and budget section models personnel retention, training, labor productivity and budget variation. Labor retention is key to effective standards operation. In international standards bodies it takes years to be effective in standards committee operations, gain positions of influence, and obtain standard approvals.

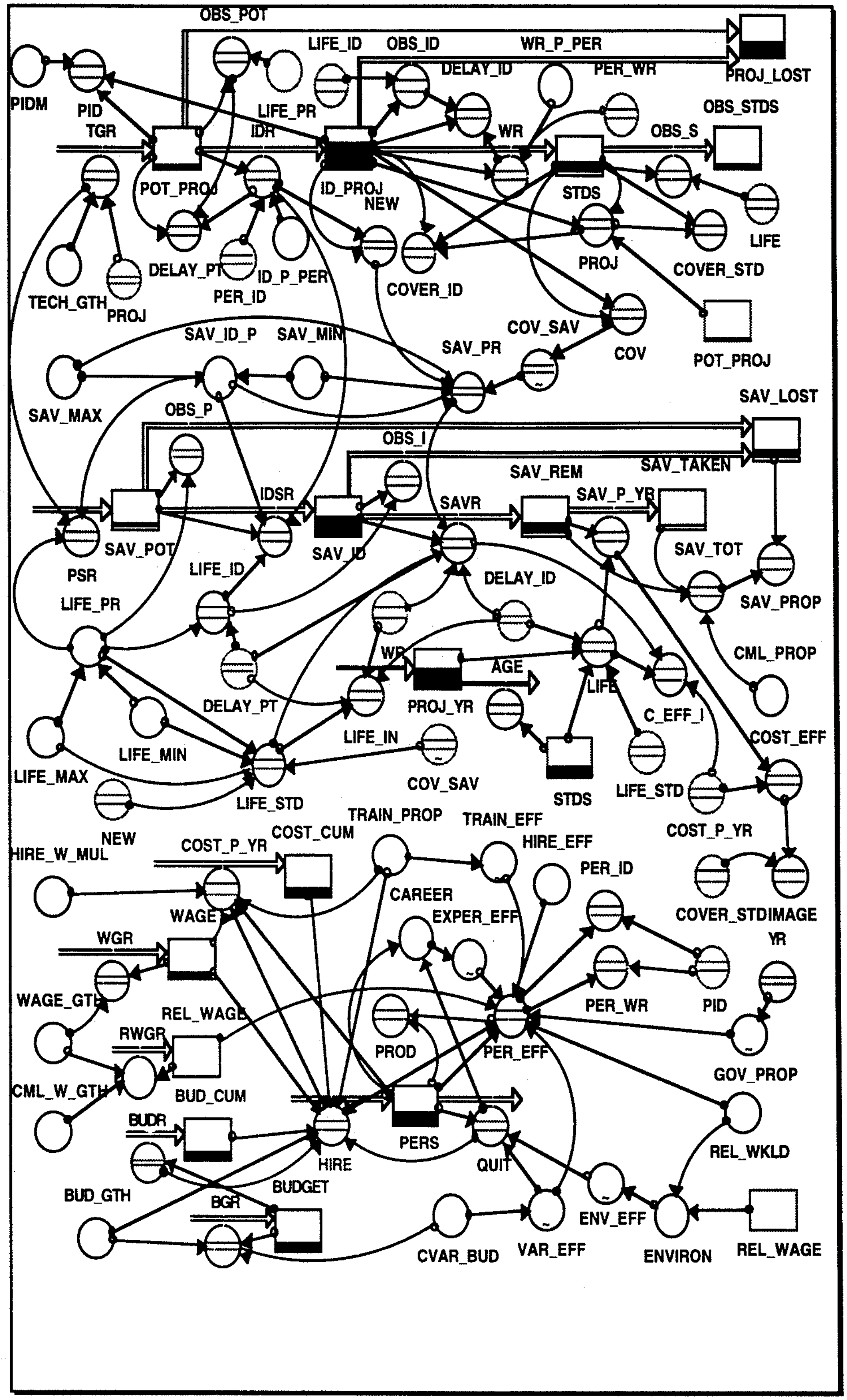

Figure 1. Complete Model

Results

Figures 2 through 7 show the results of the baseline standards model run over a 20 year period. Figure 2 shows the project levels. Initially there is a fast decline in potential projects as they are identified. Later completed standards increase at a decreasing rate. Both obsolete standards and lost while waiting levels accumulate values from the beginning of the simulation. Thus they constantly increase.

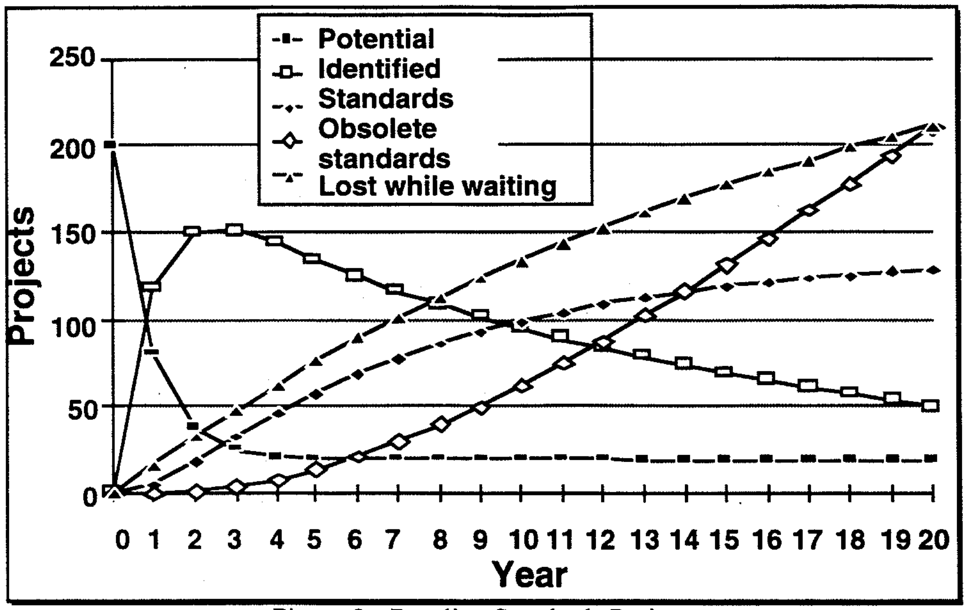

Figure 2. Baseline Standards Projects

Figure 3 shows savings in millions of dollars. The first three levels reach stability around year eight. Note since savings taken and lost accumulate values from the beginning of the simulation, they increase throughout the run.

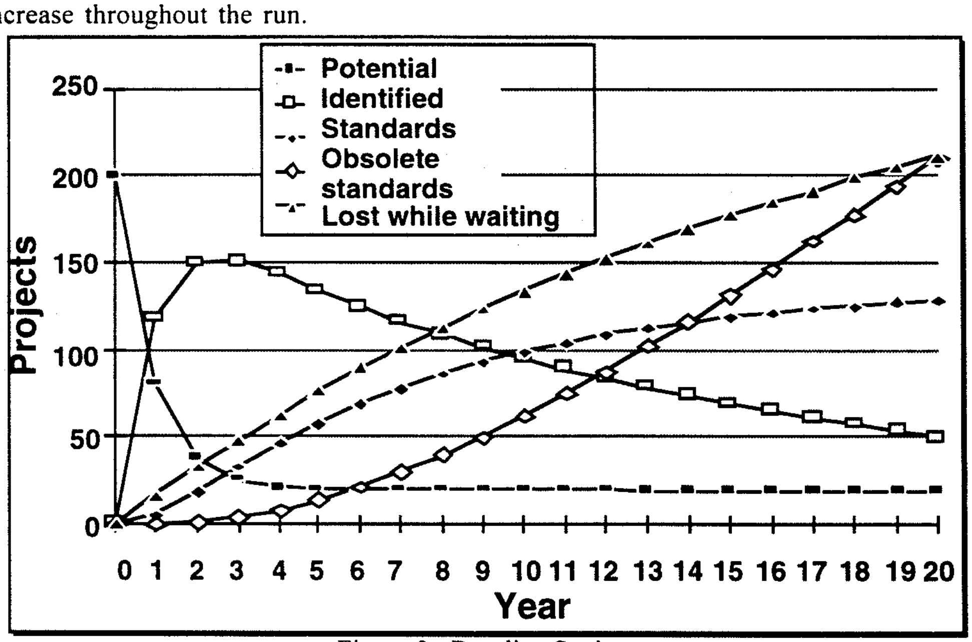

Figure 3. Baseline Savings

Figure 4 shows the optimal allocation of personnel between the identification and writing tasks for the baseline values. Initially everyone is assigned to identification. There is a speedy reallocation to writing which stabilizes in year 4. Identification personnel increase after year 4 in an attempt to keep up with the technology growth rate. In the base case technology is growing at 10 percent per year while the standards budget is growing at 5 percent per year.

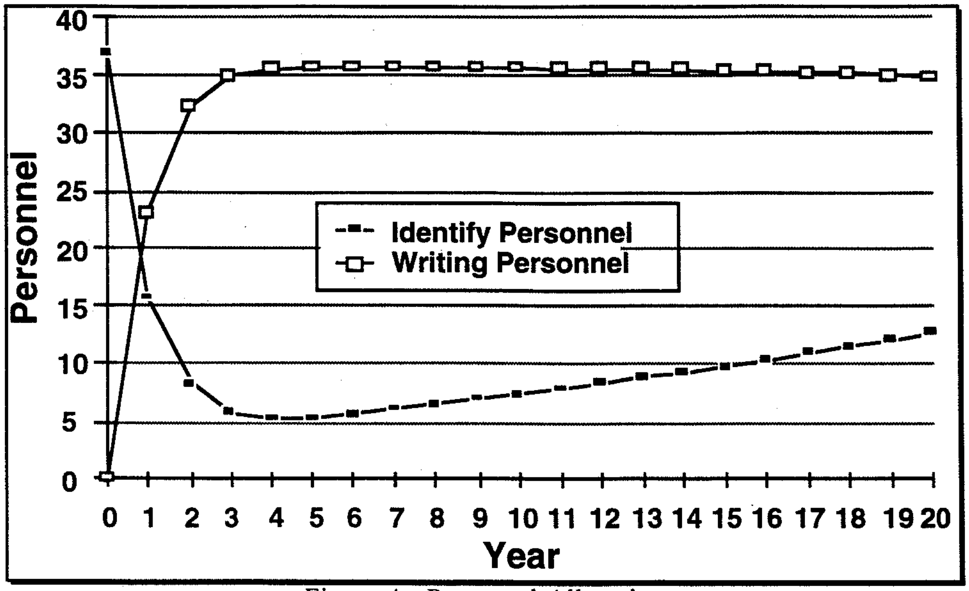

Figure 4. Personnel Allocation

Figure 5 shows the performance proportions. Identification coverage reaches 90 percent by year 4. Standards coverage increases at a decreasing rate throughout the run, reaching 65 percent coverage in year 20. Savings proportion peaks in year 5 at 58 percent and slowly decreases thereafter. This is because less cost effective projects must be chosen as coverage increases. The results are highly dependent on the parameter values chosen, so a sensitivity analysis around the baseline values was performed.

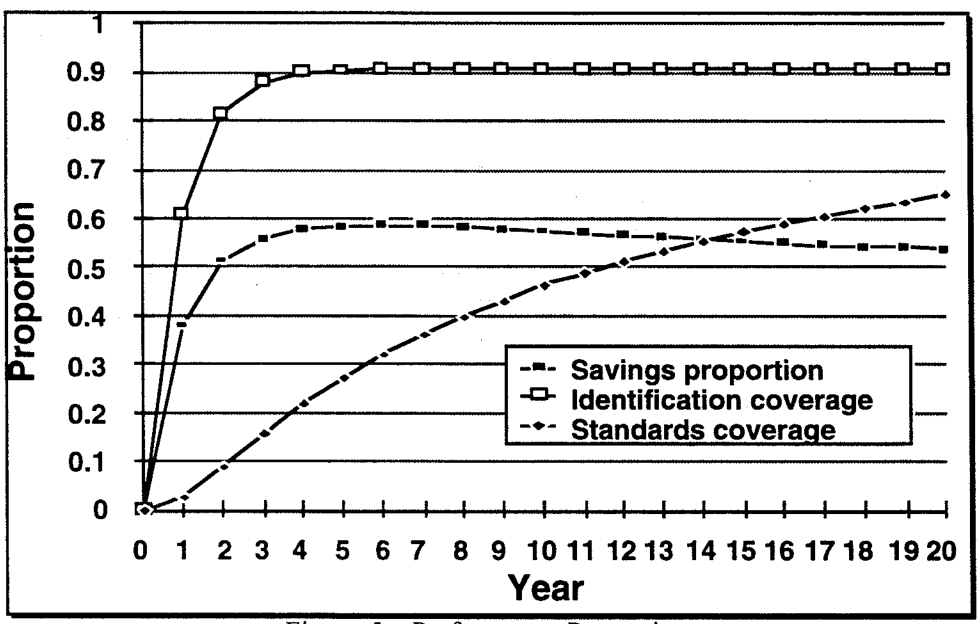

Figure 5. Performance Proportions

Figures 6 and 7 present the results of this analysis. The center bar is the base case value. The bar to the left gives the result when this parameter is set to the low level and all other parameters are at their baseline values. Similarly the bar above is when the parameter is set to the high level. The high and low levels are indicated in the parameter label. The baseline level is midway between these values.

The first four parameters are environmentally set and are thus not controllable. They are maximum project savings, maximum standard life, technology growth rate, and initial potential standards projects. The project savings were beta distributed between 1 million dollars per year and the specified maximum value. The minimum maximum range was set to 6 standard deviations and the mean was set midway between the minimum and maximum. Standard life was similarly beta distributed between 5 years and the specified maximum life. To qualify as a project, savings must exceed one million dollars per year and standard lifetime must exceed 5 years.

The last four parameters are controllable to some degree. They include annual standards budget, annual standards budget growth rate, identifications per person, and relative government wage rate. Initially the standards writing rate was set to a tenth of the identification rate (takes ten times the personnel to write the standard as to identify it).

Figure 6 shows total savings (both taken and remaining) by year 20 in billions of dollars. The wide range in values is due to the initial uncertainty in parameter values. The range will be reduced as more estimates are received. Note that there are lower savings for the high technological growth rate. At 15 percent technological growth and 5 percent standards growth there are insufficient personnel to keep up with the identification task. An increase in initial potential projects from the 200 baseline to the 300 high level results in very little increased savings for the same reason.

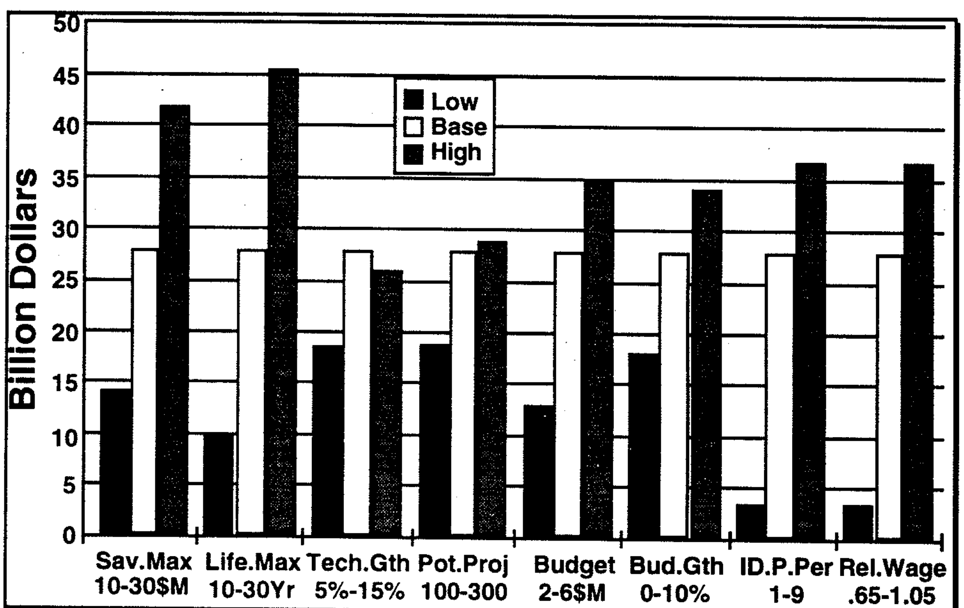

Figure 6. Total Savings By Year 20

Figure 7 shows standards coverage in year 20. Note that the annual savings per project distribution has no effect on coverage. Increases in standard lifetime, technological growth rate, and initial potential projects all reduce standards coverage. Standards coverage does not include lost or obsolete projects. Longer standard life leads to more projects in the potential or identified levels since they take longer to become obsolete or lost.

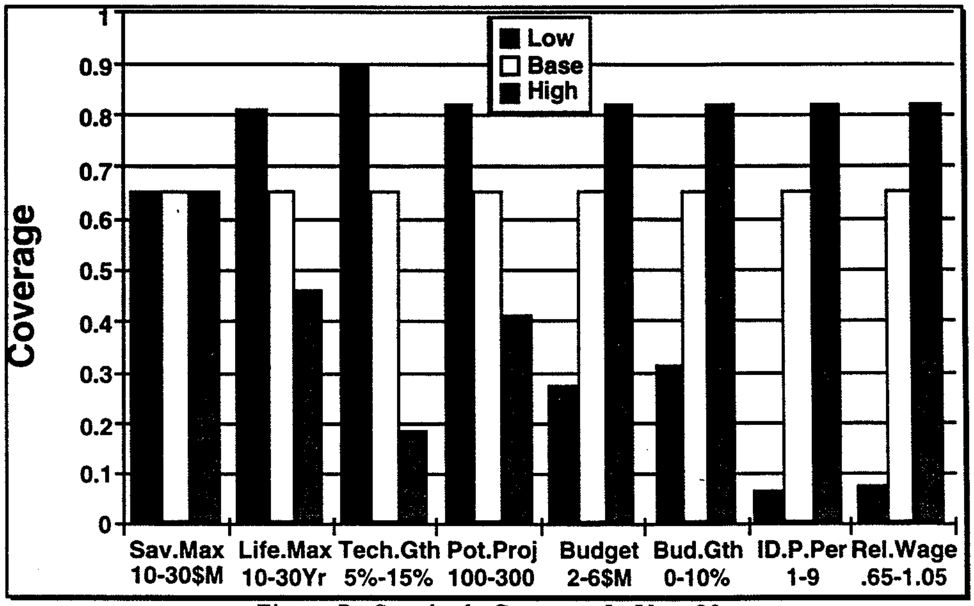

Figure 7. Standards Coverage In Year 20

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