A SYSTEM DYNAMICS MODEL FOR AUTOMATION

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ABSTRACT

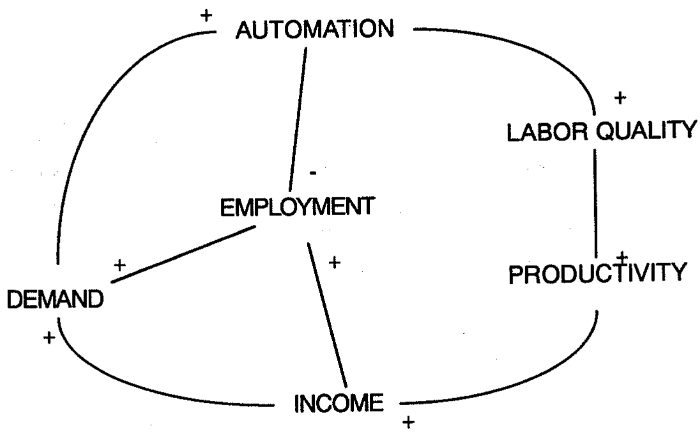
A system dynamics model is presented in this paper along with the results of simulation of some policies and their consequences automation. The automation seems to be the answer for faster growth and development throughout the world whether or not there is excessive labor or its shortage in a nation. Higher productivity, lower costs, better quality of products and services, remaining competitive and new innovations are benefits of automation and they are very important factors in industrialization and as well as in sustaining the jobs in the long run. Very often, particularly in the developing countries, the politicians either exploit or in most cases misunderstand the total effects of automation and computerization. In India, for example, computerization of even very important services like airlines and trail reservations, insurance and banking have suffered due to political decisions for two decades. Only recently they have realized their mistakes and are trying to catch up. This simple system dynamics model can be easily used for systems analysis to study the effects of automation and thus can help in making strategic decisions in automation and policy guidelines formulations.

INTRODUCTION

Whenever new automation technology is available for adoption, the contraversial question of its effect on employment is raised. The consequences of automation have been a continuous topic of debate among politicians , economist, and social scientist [2][4][5][6]. The introduction of automation is a very sensitive issue for management and labor relations. Management looks at the prospects of improved quality of products or services, cost savings, and long term growth to maintain a competetive edge [7][8][9]. But labor unions worry at its imact on their present and future jobs. Labor is generally very suspicious of automation. Governments , particularly in developing countries where unemployment and under-employment are already a problem, find the justification of automation even more difficult to accept [3]. Many times the issues are politicized to exploit fears of labor to the advantage of some politicians. Meanwhile, precious time and opportunities are lost which could have aided a faster pace of development.

A case in point is the computerization of industries and some important services in India. Until the late 70's computer activity in India was limited to a few select universities for research and education. Further, IBM marketed obsolete 1401 computer systems in some industries at a very high price in the absence of competition. The culprits were indecisive government policies on the import and licensing of new technology and opposition from labor unions. Consequently, many industries and important services were unable to use computers to improve the performance of their operations. Air line and train reservation systems as well as banking and insurance services deterioted as they expanded. Labor unions were successful in delaying or cancelling the plans of computerizing these services. But, now in the 80's, the scene finaly seems to be changing. Over 100 companies have been registered in India. Computers have already been introduced for air and train reservations. Recently a few unions have agreed to allow the use of computers in front line banking operations[1]. Unfortunately this delay has already cost in lost production, product and quality, savings , and potential job expansion. Electronics in India grew 40% in 1985-86 year to over $2 billion. Texas Instruments (TI), Hewlit Peckard, and IBM have become potential investors. Some of them have already set up their operations. TI uses satellite communication to develop software in India for export.

FIGURE 1
CAUSAL DIAGRAM



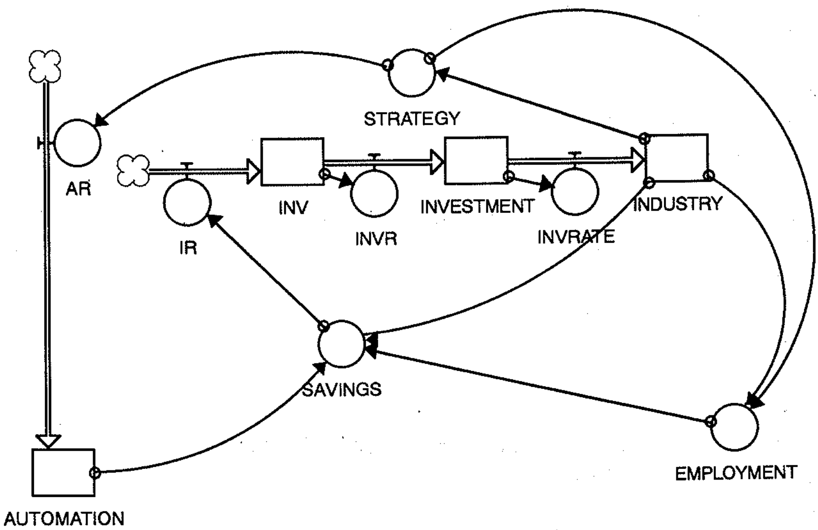
Software export from India is growing at over 40% per year. To sustain this activity India can hardly afford not to invest in fifth generation computer technology and robotics. Current research investments in these areas are about $100 million.

A simple and compact system dynamics model to formalize the qualitative long term consequences of automation is discussed in this paper. The idea is not to try to analyze any specific data or make conclusions from an empirical model, but to rather draw the causal diagram and feedback structures of the system to clarify the interactions of its important variables.The emphasis on the results is to compare different scenarios of automation policy changes and their impact on long term consequences in unemployment. The model should serve in focusing on the issues of automation and in determining a long term strategic policy to serve as a guideline for government, management, and labor. It may help clarify government dilemmas and educate labor and management of their future interests.

SYSTEM DYNAMICS MODEL

A causal diagram of automation using the feedback principles of system dynamics is presented in figure 1. The proponents of automation argue that it improves the labor quality which results in increased productivity and product quality.

FIGURE 2
AUTOMATION - SYSTEM DYNAMICS FLOW DIAGRAM



Increase in productivity and the efficient use of materials reduces production costs that result in increased net income. Income generates more demand of products which influences innovation and more automation. This positive growth cycle generates more wealth which contributes to further the development of society. The Industrial revolution in the west and in Japan confirm this point of view. However, the opponents of automation and computerization claim that it takes away human jobs and increases unemployment. The causal diagram incorporates both of these arguments. Automation may replace some jobs, thus reducing the employment at the time of its introduction. However, Increased income as a result of automation will add to new jobs in the future. This coupled scenario is sketched in the causal diagram.The System Dynamics Diagram of this model is given in figure 2. The variables used in the modeling are explained in the following.

AR - automation rate
IR - Investment rate in industrialization
STRATEGY - The percent of industry being automated per year
SAVINGS - Total savings generated in the industrial part of the economy
EMPLOYMENT - Model related employment
INDUSTRY - Actual level of industrialization
INV,INVR,INESTMENT and INVRATE are used as rates and levels to incorporate second order delay from IR to INDUSTRY level as shown in figure 2.
The unit of EMPLOYMENT is actual number and all other units are money.

The system equations for representing the system dynamics flow diagram are written as :

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AUTOMATION = AUTOMATION + dt * ( AR )
INIT(AUTOMATION) = 10000
INDUSTRY = INDUSTRY + dt * ( INVRATE )
INIT(INDUSTRY) = 1000000
INV = INV + dt * ( IR - INVR )
INIT(INV) = 0
INVESTMENT = INVESTMENT + dt * ( -INVRATE + INVR )
INIT(INVESTMENT) = 0
AR = STRATEGY
EMPLOYMENT = INDUSTRY/1000-STRATEGY/200
INVR = INV/3
INVRATE = INVESTMENT/2
IR = SAVINGS
SAVINGS = INDUSTRY*0.04+EMPLOYMENT*50+AUTOMATION/10
STRATEGY = 0.05*INDUSTRY
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The total employment numbers (EMPLOYMENT) is defined as a function of active amount invested in industries (INDUSTRIES). The example which assumes 1000 money units of investment in Industry creates one job. Similarly one job is assumed to be lost for each new investment in automation of 2000 units. Above, equation of the total savings available for new investmens (SAVINGS) is defined as the sum of industrial growth factors (4% of current investments in the industry), savings from employed population (50 units per person), and the cost savings from the automation (10%). STRATEGY variable defines the automation rate (5%).

The model has been run with many changes to test their validity as well as their sensitivity to confirm to reasonable arguments. The models most important parameters are SAVINGS and STAREGY. The focus on testing was also to see the changes in the model's behavior from the changes in these parameters. Again the objective is to see the trends in employment change.

FIGURE 3
AUTOMATION RATE (1% per year)

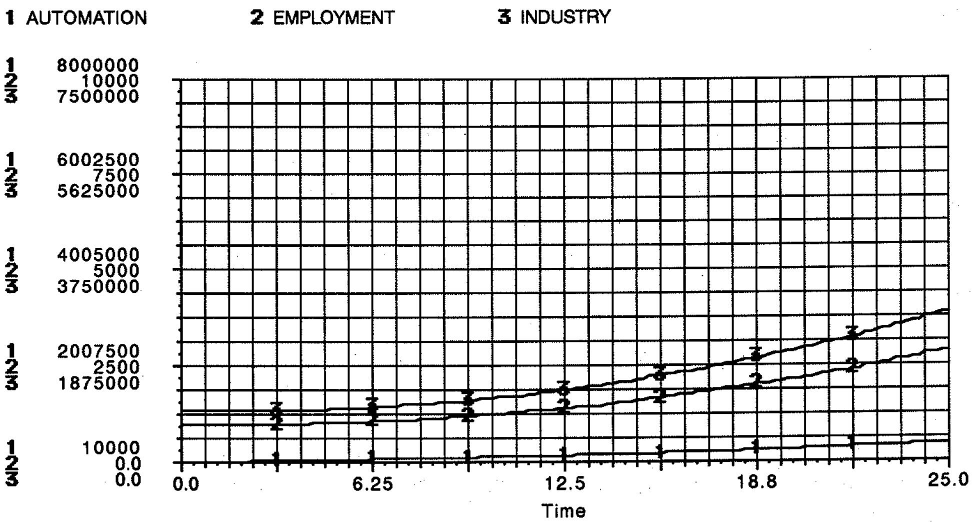
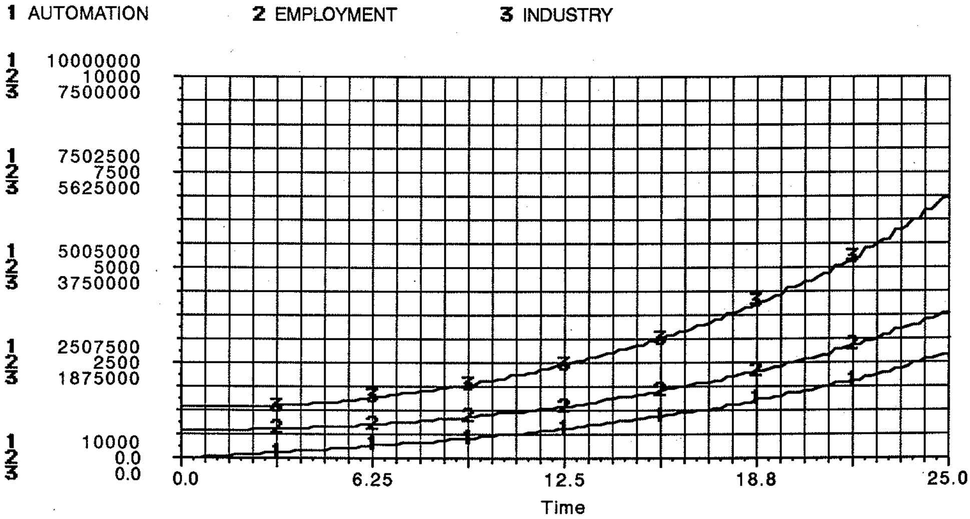


Figure 4
AUTOMATION RATE (5% per year)



RESULTS

The graph in figure 3 is generated from the simulation of the model using STELLA . This graph shows the policy of very low (1%) rate of automation in existing industries. The graph in figure 4 is obtained by changing the automation rate to 5%. The growth in employment is much slower with a lower rate of automation. If loss of innovation and international competetiveness were also taken into consideration in the model, then the difference in employment would be even greater. At the end of the 25 year period, the difference in the total number of jobs is 1000 which is abot 40% more than in figure 2. Also the income per person increases as the rate of automation accelerates. This would be reflected in the form of newly created jobs which generally command higher salaries. A one time loss due to automaton is in part compensated by new job requirements. But the most significant factor is an increase in savings due to automation which continues to be generated ever after its introduction. It is this saving that generates new types of products, services, and jobs.

Automation and employment being contrary to each other is a myth. Governments, managers, and labor unions must be educated through simple models that automation is a friend and not a foe. Historically, through automation, man has achieved better standards of living. Before the industrial revolution, jobs did not exist in automobile, chemical, computer, or farming machine industries. Most farming jobs of yesterday have been beneficially replaced by others because of automation in the last one hundred years. In coming years computers are going to change the quality of jobs and improve the standard of living throughout the world.

The model presented in this paper is used to clarify and accomodate diverse view points. This aspect of system dynamics methodology has not been explored to its fullest potentials in the area of clarification of diverse arguments on economic activities. With the system dynamics technique of causal diagram many important aspects of feed back structure of a sytem are easily incorporated. The simulation model , then, can be used to find the long term effects of various strategic decisions in the form of trends. The model is an example application where arguments like 'Automate or Liquidate' [2] and 'Where Will All The People Go' can be programmed together to clarify the arguments. In the automation controversy case, the clarifications can be summed up as "Automation is essential for development". To improve the quality of products or services and to remain competetive automation is indispensible. Fortunately this also brings improvements to the quality of life. Any reduction in employment from automation, in general, is more than compensated from futher job creations out of investments that become available due to cost savings from automation.

REFERENCES

Articles:

[1]. The Computerization Of India; Times Of India, World Press Riview 1987.

[2]. Automate Or Liquidate; Management Today; Oct. 1985

Papers:

[3]. Corden W.M. and Findlay R. ; Urban Unemployment, Intersectorial Capital Mobility And Development policy ; Economica ; Feb. 1975

[4]. Fehl S.; The Challenges of Factory Automation; Production Engineering

[5]. Gang I.N. and Gangopadhayay S.; Employment, Output and Choice of Techniques : The Trade Offs revisited; Journal of Development Economics 25 (1987)

[6]. Guteri F.V.; Quality Goes High Tech; Business Monthly

[7]. Homer J.B.; Theories Of Industrial Revolution: A Feed Back Perspective; Dynamica, Volume 8 Part 1; 1982

[8]. Mcmillan C.J.; The Automation Triangle: New

[9]. Tsuiji Yoshihide; Japan Helps To Promote Computerization in Developing