

A Generic System Dynamics Model of Firm Internal Processes

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Abstract:

This paper introduces a general system dynamics approach to simulate the internal organization of a typical for-profit firm in order to measure and predict the cumulative impacts of various managerial policies on the long-term financial performance. Through analyzing the causal linkages, we model the financial subsystem and then the operational and organizational subsystems affecting the financial variables. The outcome model consists of many stock and flow variables, which interact with various financial and nonfinancial managerial policies. Our causal structure is reminiscent of the cause and effect relationships among the Balanced Scorecard aspects, but somewhat from a more systematic viewpoint.

Our model though being simple and general provides a systemic basis and reference to develop specific customized models for actual firms and then evaluate their managerial policies and decision rules using simulation. In each case, this model have to be re-configured and its parameters need to be discovered via proper field study. A simple numerical example shows how the model works.

Keywords:

Corporate Planning, Optimal Control, Performance Measures, Management Flight Simulator

1. Introduction

Success or failure of corporations has been measured by referring to some financial statements such as income statement, balance sheet and cash flow statement. In this sense, standard accounting system has been and will be a foundation for our business activities. However, the financial accounting system only includes historical information, and thus it is about facts that occurred in the past. This system can tell us little about the future of a company. This paper uses a system dynamics methodology to simulate a firm's internal interactions, measuring and predicting the cumulative impacts of various managerial policies on the firm's financial performance in long run. Among those policies are financial decision rules, operational decision rules, research and development decision rules and strategic planning decision rules.

As Forrester (1968) states, mathematical models make controlled experiments on firm systems possible and allow us to see the effects of separate parts of the system. A management laboratory or management flight simulator then becomes possible for the design of improved managerial policies. System Dynamics is a tool for designing policies and organizational forms. It is based primarily on descriptive information already available, not on statistical data alone.

Financial statements are imperative for better management of corporations, while system dynamics offers a tool to analyze and assess the management strategies. In fact, we need to understand the accounting system in terms of system dynamics. Melse, (2008) explores the foundation of the financial accounting model. The accounting equations are defined as a dynamic stock and flow model expressing the two dimensions of the double-entry accounting system. He concludes that the dynamic accounting model can be used for strategic planning and control purposes and integrated within a system dynamics model designed for such purposes.

Qureshi, (2007) develops a system dynamics model to identify investment; financing and dividend policies that may help maximize the firm value. This study simultaneously tests various combinations of these policies that may help maximize the firm value. As he suggests adequate investment in productive assets and a low debt capital structure play dominant roles to maximize the firm value. A consistently stable dividend policy is also a prerequisite of firm value maximization. Nair and Rodrigues (2013) develop a system dynamics model for the financial accounting of a manufacturing firm and simulate the effects of increase in production on the variations in Net cash flow, Gross income, Net income, Pending bills, Receivable bills, Debt, and Book value. The financial experts can use their model (like ours) as a decision support tool in arriving at conclusions related to the expansion plans of the organization.

Financial measures only tell a fraction of a company's story. Therefore, practitioners and scholars have tried to incorporate organizational and other functional performance measures. Kaplan and Norton (1992) developed the concept of Balanced Scorecard (BSC), proposing that performance measurement systems should be based on a balanced approach of interrelated metrics, instead of only financial performances. This scorecard translates the vision and strategy of a business unit into objectives and measures in four different areas: financial, customer, internal business process, and learning and growth. As Kaplan and Norton (2004) present, there is a causal chain through all four perspectives: measures of organizational learning and growth influence measures of internal business processes, which in turn, affect measures of the customer perspective; and they all drive financial measures. This is a balance between lagging (outcome measures) and leading (performance drivers) indicators, and between financial and nonfinancial measures. The time delay between various measures has been discussed as one of the main unsolved problems in BSC. In this light, System Dynamics will be of irreplaceable support.

Akkremans and Oorschot (2004) use system dynamics modeling to develop a BSC for management of one organizational unit of a leading Dutch insurer as a case study. They use qualitative causal loop diagramming followed by quantitative simulation. The system dynamics approach, proved beneficial in analyzing the relevance of the measures contained in the BSC. It illustrated how seemingly contradictory goals such as customer satisfaction and employee productivity were mutually reinforcing. In addition, analysis of their results showed how performance would first have to drop further before significant improvements could be realized. In addition, they discuss some limitations of the BSC, such as its inability to distinguish delays between actions and their impact on performance. Using System Dynamics may be the only way to solve one of the main difficulties connected to BSC, namely the time lag dimension.

The System Dynamics approach for BSC provides an idea of time delays on the outcome from altering input variables. Nielsen and Nielsen (2008) use a particular case study that can be regarded as an experimental one. The purpose of this research was to develop new accounting procedures from existing theoretical perspectives, using normative reasoning. In their research, they have focused on four quality concepts: construct validity, internal validity, external validity and reliability. However, an important limitation of their study was their limited access to confidential information and thus the model cannot be used directly in a practical environment.

Barnabe (2011) shows that combining BSC and System Dynamics modeling techniques can help to develop a comprehensive management flight simulator to be used as a strategic management tool. Embedding A System Dynamics-based BSC into a computer-based management flight simulator would consent to retain all the advantages of the original architecture created by Kaplan and Norton, while at the same time benefiting from strengths of system dynamics methodology. One can use the management flight simulator to test feasible policies before their implementation and develop a synthetic scenario analysis. This System Dynamics methodology combined with the traditional BSC architecture is useful in the development of dynamic scorecards that can offer fundamental support for decision-makers facing complex and dynamic domains.

The majority of works done in this field have primarily focused on some specific aspects of the dynamics of the firm. However, this paper tries to consider all the financial flows as well as the operational flows that have financial consequences in the firm. In this regard, cause and effect relationships are analyzed to move backward from the long-term financial results (cumulative profits) to the financial variables, operational variables and organizational variables. During this process, the effects of financial decisions, operational decisions and organizational decisions made by corporate managers are taken into consideration. In fact, System Dynamics is used to evaluate the value of a corporation. The model used in this paper helps managers and decision-makers to increase their knowledge about their specific business environment and become more aware and conscious of both generic and specific dynamic issues.

We build a System Dynamics model using *iThink* software; *iThink* is a modeling interface, which simulates a dynamic system by numerically solving its corresponding differential equations structure. Our model provides a laboratory or management flight simulator to anticipate the long-term financial consequences of managerial decisions and policies, thereby helping managers to make better plans. A company can use this model to make risk-free experiments by changing variables, or policies.

The next section introduces some basic concepts along with the variables used in our model. The third section presents our model. A numerical example is analyzed in the fourth section. Finally, the paper concludes in the fifth section.

2. Definitions and Variables

We use the term system to mean an interdependent group of items forming a unified pattern. Since our interest here is in business processes, we will focus on organization as a system made up of interacting parts intended to design, market, produce, and distribute products or services. Causal loop diagrams emphasize the feedback structure of a system, as Sterman (2000) explains. Stock and flows track accumulations of material, money, and information as they move through a system. Stocks include inventories of products, and financial accounts, such as debt, book value, and cash. Flows are the rates of increase or decrease in stocks, such as production and shipment, borrowing and repayment, investment and depreciation, as well as receipts and expenditures. Stocks characterize the state of the system and generate the information upon which decisions are based. The decisions can alter the rates of flow, thereby altering the stocks and commonly closing the feedback loops in the system. The behavior of a system arises from its structure consisting of the feedback loops and stocks and flows.

The diagram in figure-1 illustrates the usefulness of a graphical notation for representing system structure. It is part of the complete model presented in the next section. This shows the relationships among the elements of a production division within a company. In this diagram, the short descriptive phrases represent the elements, and the arrows represent the causal influences between these elements. We see that “Production” can increase “Inventory” and “Sales” can decrease it. “Productivity” influences “Production Capacity” which in turn directly affects “Production”.

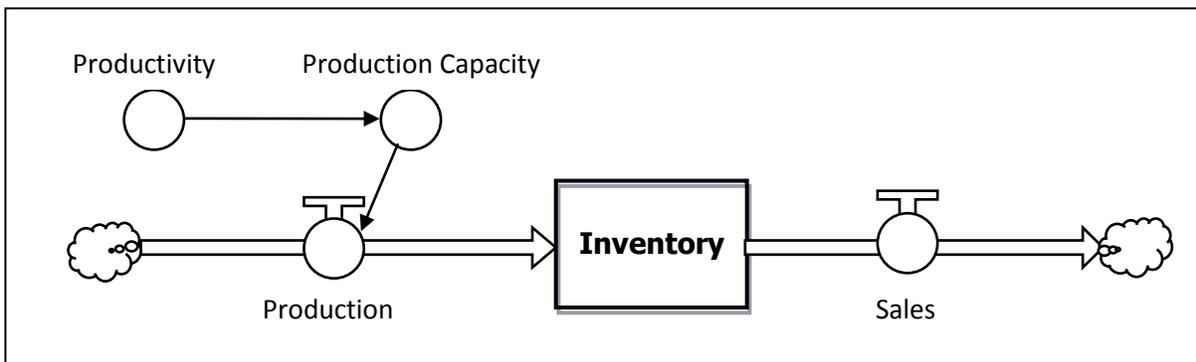


Figure-1

This diagram presents a linear chain of causes and effects that does not close back on itself. Therefore, we call it an open loop. When an element of a system indirectly influences itself, the portion of the system involved is called a feedback loop or a causal loop. As Richardson and Pugh (1981) define, a feedback loop is a closed sequence of causes and effects, that is, a closed path of action and information, or the transmission and return of information. It is often necessary to consider feedback within management systems to understand what is causing the patterns of behavior.

To introduce the variables of the model, we partition it into four major subsystems, in line with the Balanced Scorecard aspects. When necessary, the type of a variable (stock, flow, auxiliary, decision...) is specified in the parenthesis in front of the definition of the variable.

The **financial** and **accounting** variables in the model are as follows:

Payoff PV = the present value of the total payoffs to the shareholders (Stock)
Equity = accounting equity (Stock)
Assets less Debt = must be equal to the *Equity* (Auxiliary)
 $Total\ PV = Payoff\ PV + Equity / (1 + rS)^t$
Net Income = the net profit after taxes and dividends (Stock)
Dividends = dividends paid to the shareholders (Flow)
PV Div = present value of the dividends paid to the shareholders (Flow)
Retention = amount of net income retained, increasing the equity (Flow)
Retention Ratio = a ratio reflecting the dividend policy (Decision)
Debt to Equity Ratio = auxiliary variable to help make better financing decisions
rS = discount factor : cost of equity capital according to CAPM formula (Exogenous)
rB = cost of debt (Exogenous)
Continuous Interest Rate = continuously compounded interest rate [$\exp(rB) - 1$]
EBT = Earnings before Taxes (Flow)
EBIT = Earnings before Interest and Taxes
Price = average price for a unit of the product (Exogenous)
Revenue = $Sales * Price$
Gross Profit = $Revenue - Variable\ Costs$
Variable Costs = $Unit\ Cost * Sales$
Unit Costs = marginal cost of producing one more product. (*Inevitable + Controllable Costs*)
Inevitable Costs = unavoidable unit costs (Exogenous)
Controllable Costs = unit costs that can be reduced through productivity
Fixed Administrative Costs = unavoidable fixed costs due to administration. (Exogenous)
General Expenses = $Fixed\ Administrative\ Costs + Inventory\ Costs + All\ Budgets$
Tax = tax paid out of *Net Income* (Flow)
Tax Rate = tax rate according to the law (Flow)
Debt = total accumulated debt (Stock)
Interest = the interest associated with debts (Flow)
Interest Payment = amount of interest paid for debt (Flow)
Debt Issue = amount of money borrowed according to the financing policy (Decision)
Cash = total amount of cash at hand (Stock)
 $Cash\ Borrowed = Debt\ issue + Interest - Interest\ Payment$
 $Cash\ Added = Depreciation + EBT + Cash\ Borrowed$ (Flow)
Payments = the amount of *cash* paid (Flow)
Investment = the amount of *cash* invested (Flow)
Fixed Asset = total investments accumulated (Stock)
Depreciation = amount of assets being depreciated (Flow)
Depreciation Rate = rate of depreciation (Exogenous)
Capital Budgeting = a policy determining how much to invest (Decision)

The **operational** variables of the model are as follows:

Inventory = total amount of product at hand (Stock)
Sales = amount of product sold (Flow)
Inventory Costs = total cost of keeping inventories
Production = rate of producing the product (Decision & Flow)
Production Capacity = maximum rate of production
Productivity: To affect Quality Improvement, Controllable Costs and Production Capacity
Quality = quality of the product (Stock)
Standard Quality = average quality of the competitor's products (Exogenous)
Improvement = amount of increase in the quality of the product (Flow)
Process Budget = amount of money spent to improve quality (Decision)
Techno = the total knowledge and technology accumulated through research (Stock)
R&D = the rate of knowledge being acquired (Flow)
R&D Effectiveness = the effectiveness of *R&D Budget* (Exogenous)
R&D Budget = the amount of money spent to improve technology (Decision)

The **customer** aspect of the model includes the following variables:

Market Size = total demand of the product (Stock)
Substitution = the rate of decrease in the demand (Flow & Exogenous)
Increase in Demand = the rate of increase in the demand (Flow & Exogenous)
Market Share = the portion of the market available to us (Stock)
Marketing = the rate of increase in the *Market Share* due to advertising (Flow)
Competition = rate of decrease in *Market Share* due to competitors (Flow)
Aggressiveness = the strength of the competitors (Exogenous)
Satisfaction = rate of change in the *Market Share* due to the relative quality (Flow)
Advertise Budget = amount of money spent on advertising (Decision)

The **organizational** variables are as follows:

HR Skills = the total skills of the human resource (Stock)
Skills Lost = the rate of forgetting skills (Flow)
Replacement Rate = the degree of forgetfulness of the employees (Exogenous)
Training = the rate of increase in personnel skills (Flow)
Training Budget = the amount of money spent on increasing skills (Decision)
Training Effectiveness = the effectiveness of the training budget (Exogenous)
HR Motive = the total accumulated motivation of the employees (Stock)
Motivation = the rate of increase in personnel motivation (Flow)
Compensation Budget = the amount of money spent to increase motivation (Decision)
Compensation Effectiveness = effectiveness of the money spent on motivation (Exogenous)
Depression = the amount of decrease in personnel motivation (Flow)
Depression Rate = the employees' propensity to lose motivation (Exogenous)

3. System Model

To build a comprehensive model of firm, we begin with the financial relations and standard accounting equations. Then, we look for the decisions and operational variables that govern the financial variables. In this sense, we analyze the causal relationships in order to discover the drivers behind the financial variables. Then, as in BSC strategy map, we consider operational variables, organizational variables and strategic variables. In this backward modeling progression, the levels of the decision variables are not determined by the dynamics of the firm but rather by the managerial policies to be tested via simulations. Therefore, we consider firm policies as a MIMO controller which we intend to optimize as shown in figure 2. If we decompose firm into the four BSC perspectives, we will have figure-3.

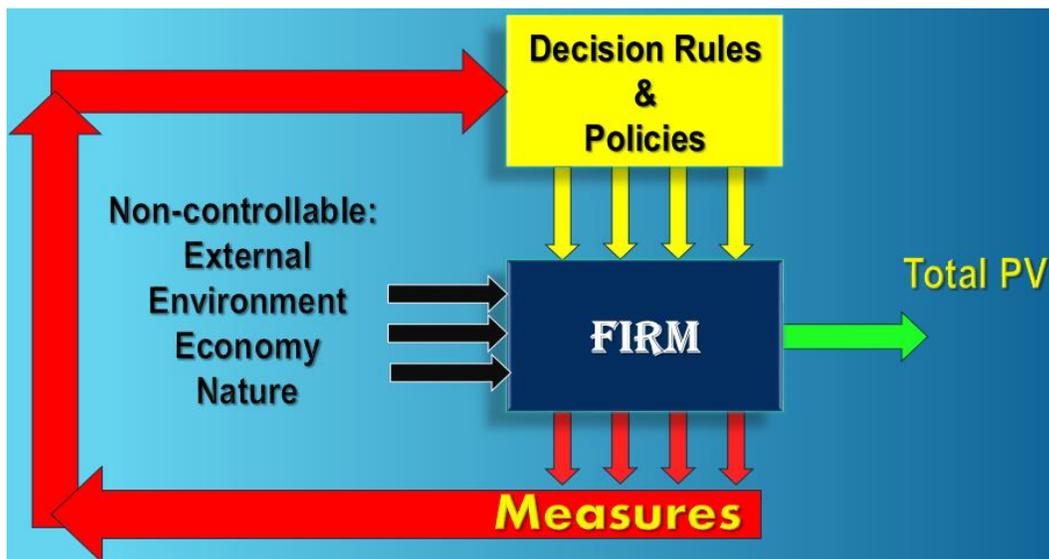


Figure-2: Policymaking as an Optimal Control Problem

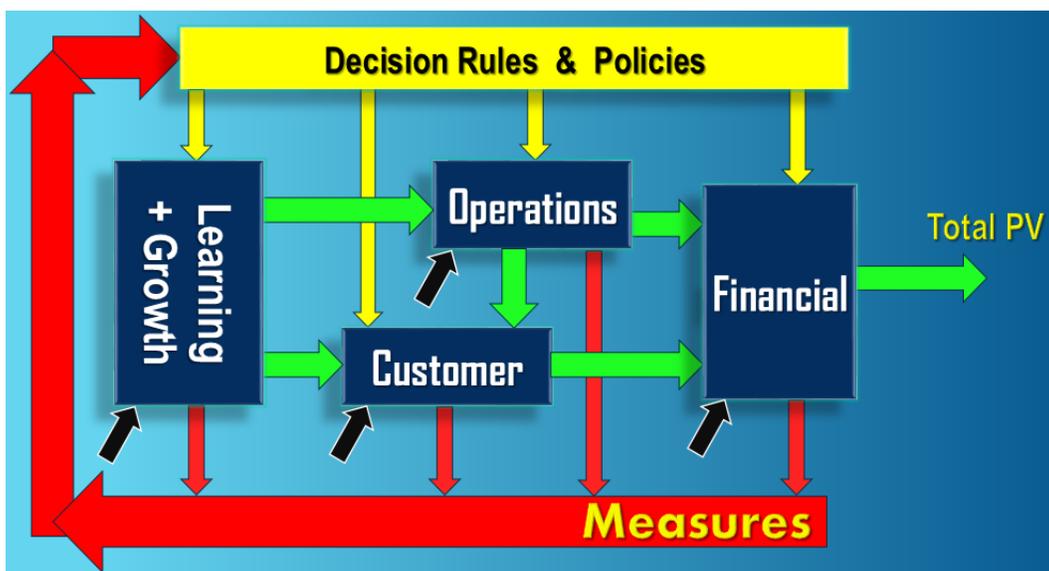


Figure-3: Partitioning firm variables into four BSC aspects

Using backward causal analysis, we can reach a complete system dynamics model for a firm. Figure-4 illustrates the complete flow diagram of our system dynamics model. In this diagram, the variables in the black boxes are exogenous variables determined by the managerial decision rules and policies. Therefore, they are the outputs of the controller. Obviously, the inputs to the controller are the measures from different parts of the system.

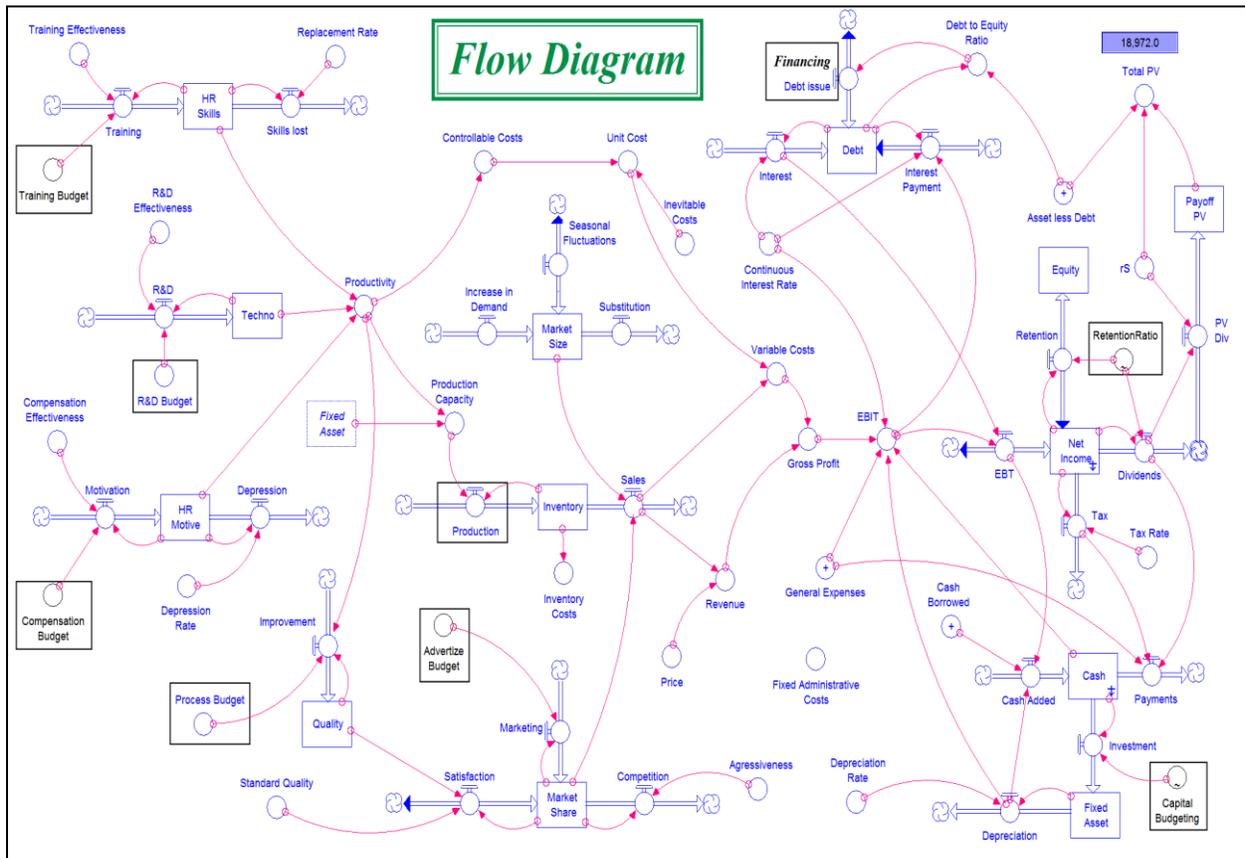


Figure-4: Complete Flow Diagram of the System Dynamics Model

The most important part of our model is the financial accounting subsystem, not just because it consists of the most significant and meaningful variables, but also due to the fact that the ultimate goal is the long-term financial success. In mathematical terms, our objective is to maximize *the present value of the total payoffs to the shareholders*, in addition to *the final equity remained for them*. We call this variable “*Total PV*”, and put it on top corner of the flow diagram. “*Payoff PV*” is a stock variable representing the first part; and obviously, the second part (*equity*) is a stock variable too. To describe the rest of the financial variables and their relationships, we need to distinguish the stocks and flows involved in the dynamics of the accounting system.

Balance sheets only consist of stock variables, whereas income statements and cash flow statements include the inflows to and the outflows from the stocks in the balance sheets. All transactions in the accounting system are recorded as inflows and outflows of stocks in the balance sheet so that each transaction causes two corresponding stocks to change simultaneously

in balance. For this purpose, each transaction is booked twice on both debit and credit sides. Inflows of assets and outflows of liabilities and shareholders' equity are booked on the debit side, while outflows of assets and inflows of liabilities and shareholders' equity are booked on the credit side.

In our financial accounting sub-model, we brought together six stock variables: *Equity*, *Debt*, *Fixed Assets*, *Cash*, *Net Income* and *The Present Value of Total Payoffs to Shareholders*. The last variable is denoted by *Payoff PV* and is defined as the accumulation of total dividends paid to shareholders considering the time value of money. In computing the present values of the *dividends* and the final *equity*, we discount their amounts by referring to rS , which stands for the firm's *cost of equity capital* and can be derived by use of *CAPM* (Capital Asset Pricing Model) formula. Notably as the balance sheet dictates, *total assets* (including *cash*) minus *debt* must be equal to the *equity*. The numerical example presented in the next section, shows that this equation holds at the end of every period, even though the variables are from different parts of the model.

Net income is a stock variable resulted from accumulation of *Earnings Before Taxes (EBT)* throughout each year, subtracted by the *taxes* at the end of the year. At the end of each year, as stated by our *Dividend Policy (Retention Ratio)*, a portion of the collected *net income* will be distributed as *dividends* to the shareholders, and the rest will be retained in the *equity*. On the other hand, *EBT* is computed continuously according to the values of *Interests* and *EBIT (Earnings Before Interests and Taxes)*. *EBIT* is calculated continuously as follows:

$$EBIT = \text{Gross Profit} - \text{General Expenses} - \text{Depreciation} + \text{Interest on Cash}$$

The last term, *interest on cash*, is the only non-operational income that we have considered. It should be noted that all the interests are computed continuously according to the continuously compounded interest rate $[exp(rB) - 1]$, in which rB stands for *cost of debt*.

The difference between interests incurred and interests paid can change the *debt* level. Also management can decide how much *debt* to issue via *financing policy*. *Debt issuance* increases both *debt* and *cash*. *Cash* is a nonnegative stock variable, which results from issuing *debt* along the accumulation of *EBT* (with *Depreciation* added back). At the end of each year, payments of *dividends* plus *tax* decrease *cash*. Furthermore, *cash* is reduced by purchasing *fixed assets* like equipment, machines, lands....

The management's *Capital Budgeting Policy* determines how much to invest in *fixed assets*. The level of *fixed assets* along the amount of *productivity* defines our *production capacity*, which in turn limits the actual *production*, to be specified by the manager.

To find *EBIT*, the value of *Gross Profit* is computed according to the following formula:

$$\text{Gross Profit} = (\text{Revenue}) - (\text{Variable Costs}) = (\text{Sales}).(\text{Price}) - (\text{Sales}).(\text{Unit Cost})$$

Sales equals to $(\text{Market Share}) * (\text{Market Size})$. However, if there is no inventory, our *current production* bounds the *sales* level. The current amount of *production* is determined according to managerial production policy and the *production capacity*. Notably, there are *inventory costs* associated with keeping inventories, which are included in the *general expenses*. *General Expenses* also include *Fixed Administrative Costs*, *Training Budget*, *R&D Budget*, *Compensation Budget*, *Process Budget* and *Marketing Budget*. All the budgets are managerial policies and can be determined arbitrarily subject to having enough *cash* available.

Marketing increases the *market share* and *competition* decreases it. Moreover, customer *satisfaction* can affect the *market share* depending on whether it is positive or negative. *Satisfaction* is positive if our *quality* is better than the *standard quality*, and otherwise it is negative. *Process budget* along the *productivity* level can improve our *Quality*. *Productivity* is the multiplication of three stock variables: *HR Skills*, *HR Motivation* and *Technology*. Management budgeting policies can improve these variables. Except for *technology*, the other two will decay as time passes, unless enough budgets are allocated to enhance them. In contrast, *technology* can only increase, referring to our assumption that knowledge cannot depreciate. This is consistent with Arenas (2012). He proposed a system dynamics model to estimate the effect of knowledge stocks on organizational performance or financial performance. He emphasize on the delay between the investments on knowledge stock and their financial paybacks. Here, we analyze this delay more systematically.

Meanwhile Arenas (2012) assumed that managers invest in knowledge stocks according to a fixed decision rule (dominant logic or managerial dynamic hypothesis). Therefore, he modeled the manager as a part of the dynamic system, whereas we regard the decisions as variable inputs to the system, so that one can use the simulation model to evaluate and compare different policies and decision rules as Bianchi et al (2013) did. As they explain, we approach the performance management problem from an instrumental view.

Personnel's ability to be productive is represented by *HR skills*, while their willingness to be productive is represented by *HR motivation*. These two stock variables are very similar. Both can increase by use of budgets (*Training Budget* and *Compensation Budget*), and both depreciate as time passes. However, the effectiveness of the budgets and the rates of dissipation, all are exogenous variables. Unfortunately, there are no well-defined units for quantifying these variables and our measures are subjective at best.

Finally, the *costs of goods sold (variable costs)* is equal to *sales* times the *unit cost*. *Unit cost* is comprised of the *inevitable costs* and *controllable costs*. *Inevitable costs* cannot be reduced, but the more *productive* our employees are, the less *controllable costs* we suffer. Hence, we can see that the *productivity* level can decrease the *unit cost* of our products, increase our *production capacity* and make the *process budget* more effective in improving the *quality* level.

4. Simple Example

Further details depend on the specific case we observe. Thus, in this section we present a simple example. We assume that our hypothetical corporation manufactures only one product and has the organizational structure of a medium size firm. The appendix contains all of the formulas required in the model, including the basic formulas of the previous section along their parameter values. Notably the *italic* formulas in the appendix are arbitrary managerial policies to be tested by the simulation.

For some financial variables, we have referred to the *U.S Composite Corporation* introduced by Ross et al (2003). Two relevant financial statements of this firm are in figures 5 and 6 as follows:

U.S. COMPOSITE CORPORATION	
Income Statement	
20X2	
(in \$ millions)	
Total operating revenues	\$2,262
Cost of goods sold	(1,655)
Selling, general, and administrative expenses	(327)
Depreciation	(90)
Operating income	<u>\$ 190</u>
Other income	29
Earnings before interest and taxes (EBIT)	<u>\$ 219</u>
Interest expense	(49)
Pretax income	<u>\$ 170</u>
Taxes	(84)
Current: \$ 71	
Deferred: \$ 13	
Net income	<u><u>\$ 86</u></u>
Retained earnings:	<u>\$ 43</u>
Dividends:	<u>\$ 43</u>

Figure-5: Income Statement data for one year

U.S. COMPOSITE CORPORATION					
Balance Sheet					
20X2 and 20X1					
(in \$ millions)					
Assets	20X2	20X1	Liabilities (Debt) and Stockholders' Equity	20X2	20X1
Current assets:			Current liabilities:		
Cash and equivalents	\$ 140	\$ 107	Accounts payable	\$ 213	\$ 197
Accounts receivable	294	270	Notes payable	50	53
Inventories	269	280	Accrued expenses	223	205
Other	58	50	Total current liabilities	\$ 486	\$ 455
Total current assets	\$ 761	\$ 707			
Fixed assets:			Long-term liabilities:		
Property, plant, and equipment	\$1,423	\$1,274	Deferred taxes	\$ 117	\$ 104
Less accumulated depreciation	(550)	(460)	Long-term debt ¹	471	458
Net property, plant, and equipment	873	814	Total long-term liabilities	\$ 588	\$ 562
Intangible assets and others	245	221	Stockholders' equity:		
Total fixed assets	\$1,118	\$1,035	Preferred stock	\$ 39	\$ 39
			Common stock (\$1 par value)	55	32
			Capital surplus	347	327
			Accumulated retained earnings	390	347
			Less treasury stock ²	(26)	(20)
			Total equity	\$ 805	\$ 725
Total assets	\$1,879	\$1,742	Total liabilities and stockholders' equity ³	\$1,879	\$1,742

Figure-6: Balance Sheet data for two years

We use *iThink*® software to simulate the dynamics of this firm for 30 years of activity which is enough to be regarded as *EVENTUALLY*. The simulation yields several plots, of which the most important ones are presented in figures seven and eight. Figure-7 is important because it shows that total *assets* (including *cash*) equals *equity* plus *debt* at the end of each year. Notably their values are derived from different parts of the model. Therefore, this plot endorses our accounting model.

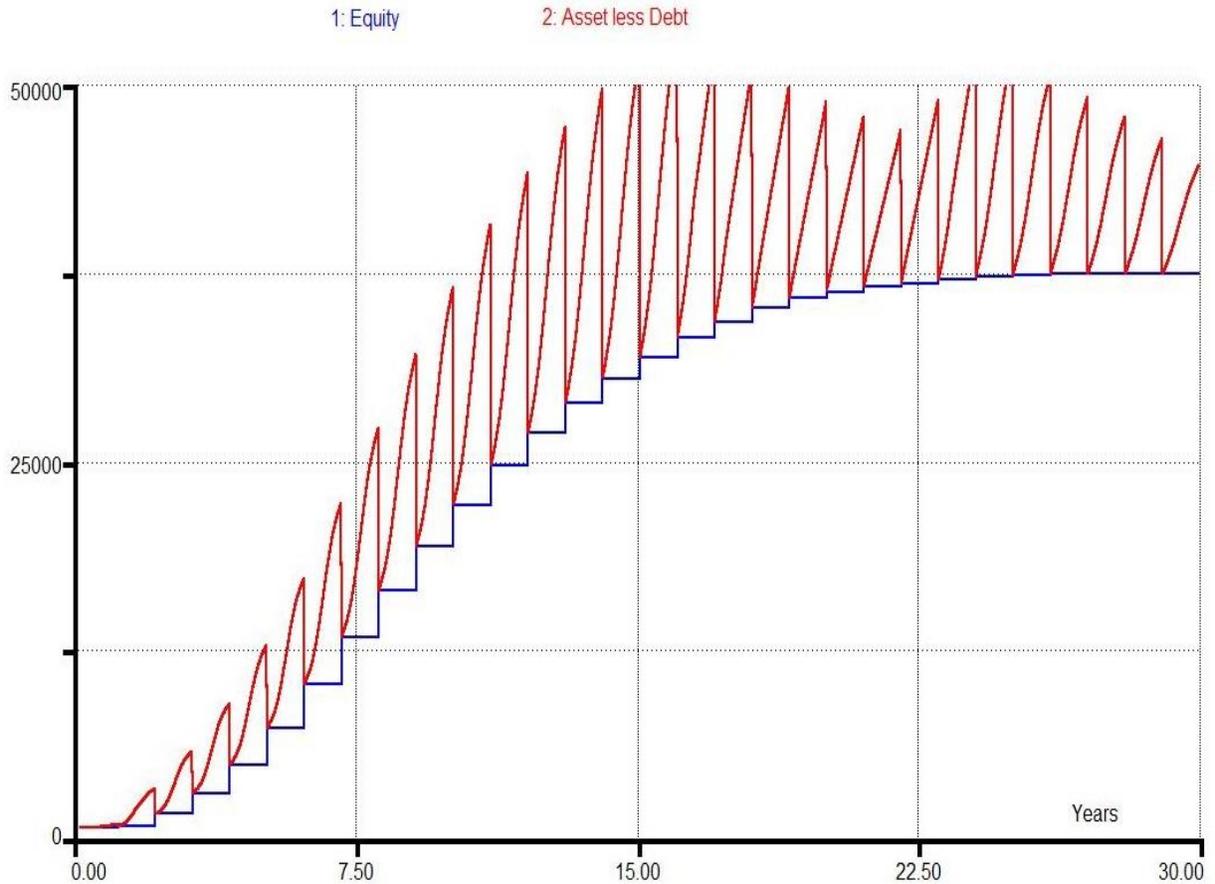


Figure-7: Balance Sheet

The next important plot shows *the present value of total returns to shareholders*. As we explained earlier, *Payoff PV* is a stock variable that accumulates the present value of dividends paid to the shareholders. In addition, this variable plus the final *equity* is defined as *Total PV*, which its maximization can be our ultimate goal when designing any managerial policy or decision rule. These two important variables are illustrated in figure 8. Obviously, the present value of equity in far future is near zero and thus the two plots converge because in long term only *Payoff PV* matters.

Figure-9 shows the proportion of debt to equity at each point in time. This variable presents the financing and liability status of the firm. Figure-10 shows cash and figure-11 shows net income. Figure-12 shows the unit cost of product, which depends on productivity. Figure-13 illustrates product quality, which affects customer satisfaction and thus market share. Figure-14 shows how the market share changes throughout our time horizon. Figure-15 shows the level of inventory, which depends on sales as well as production rate.

System Dynamics Model for Firm

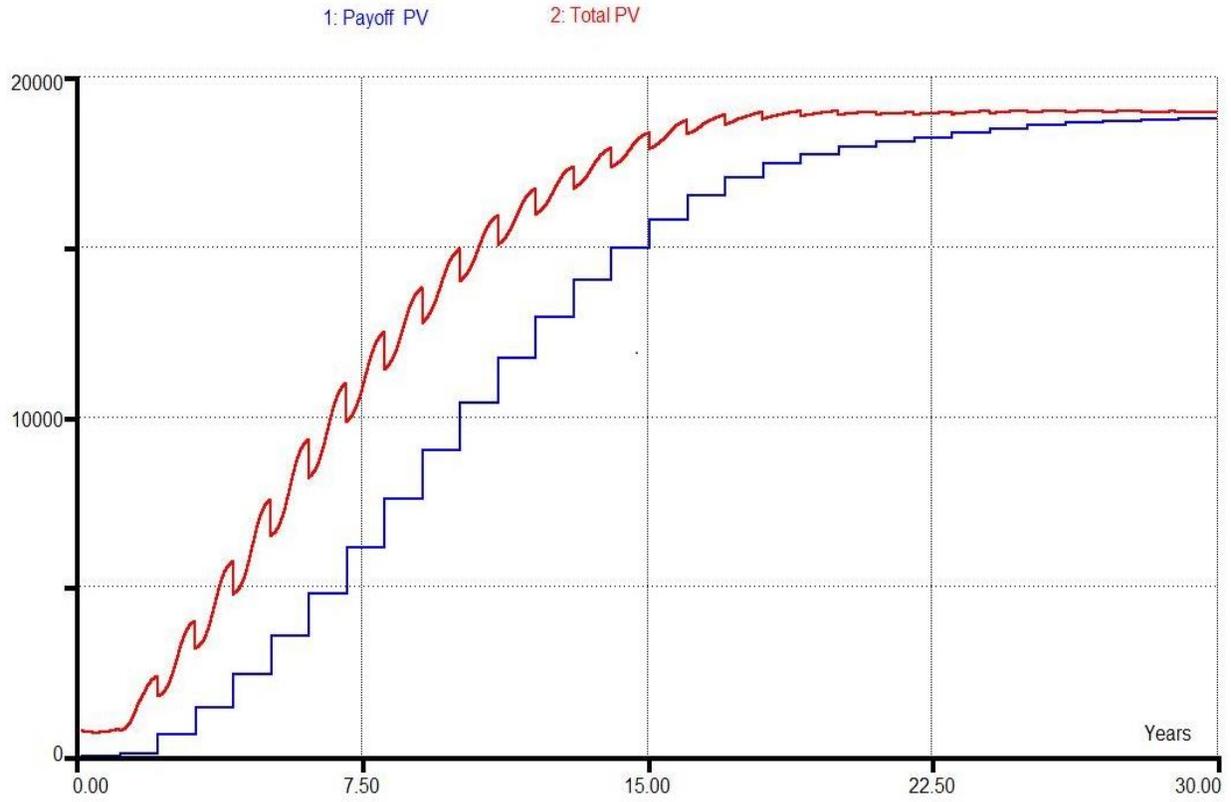


Figure-8: Returns to shareholders

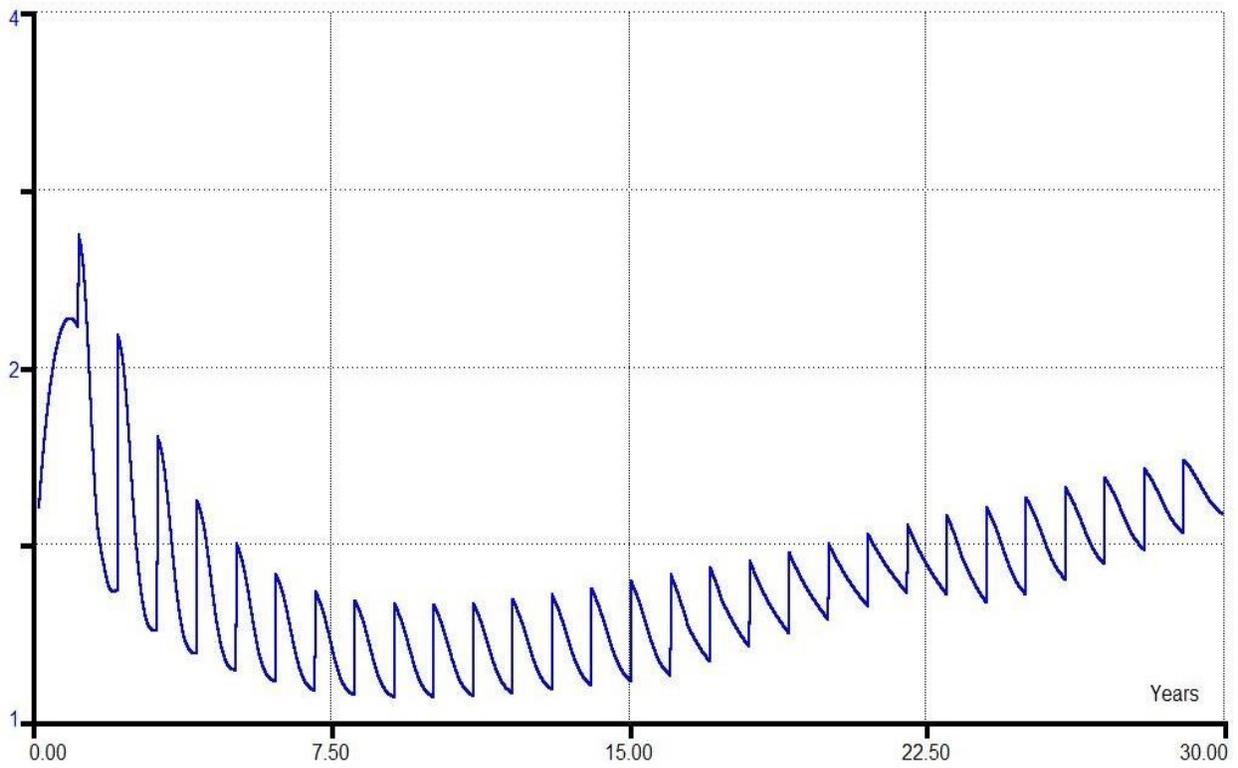


Figure-9: Debt to Equity ratio

System Dynamics Model for Firm

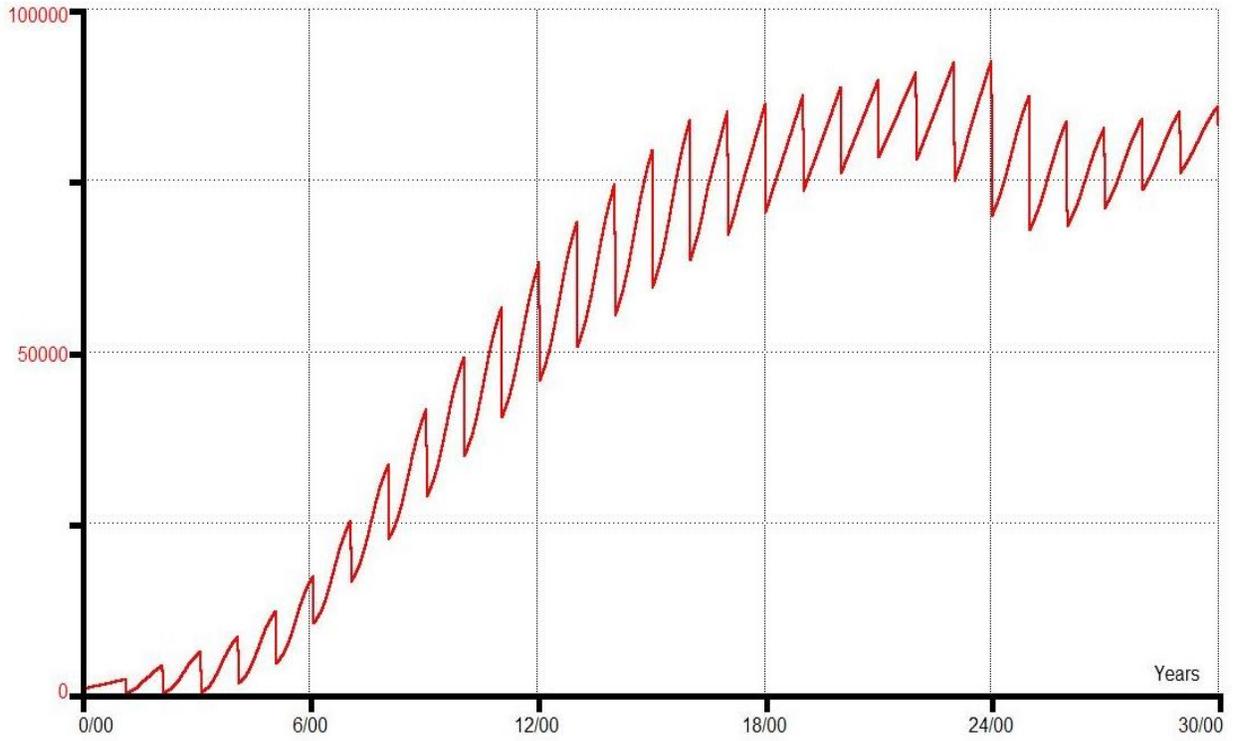


Figure-10: Cash

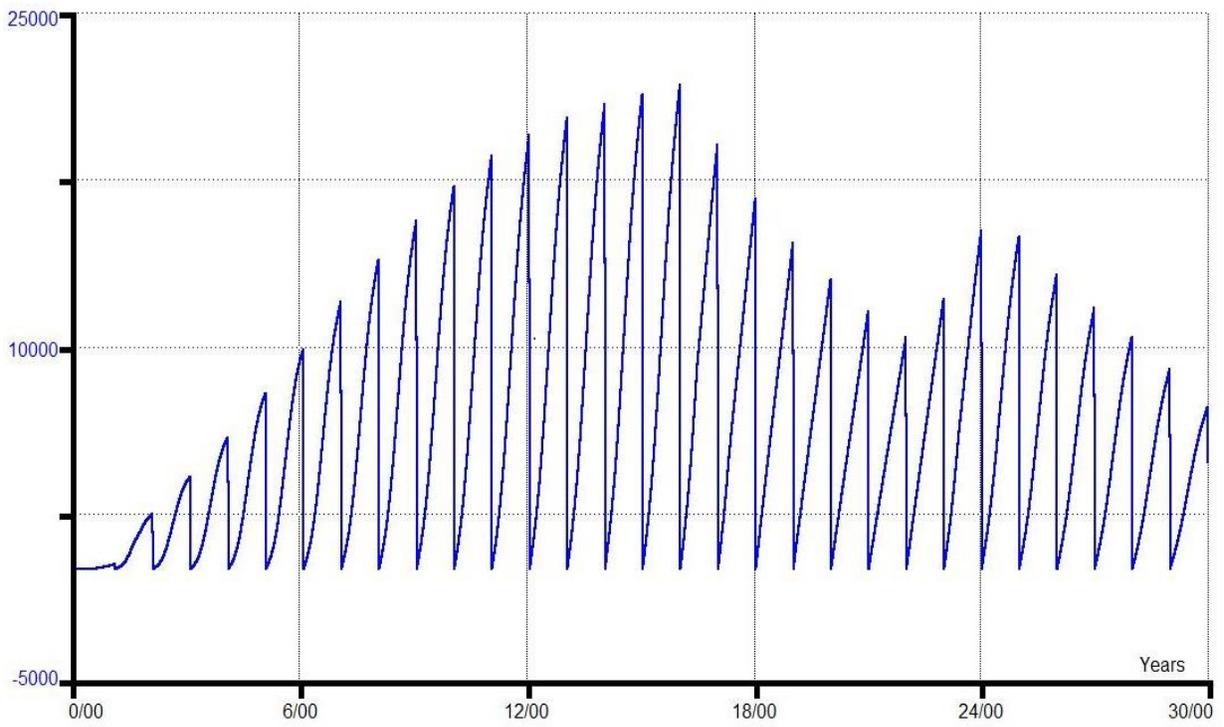


Figure-11: Net income

System Dynamics Model for Firm

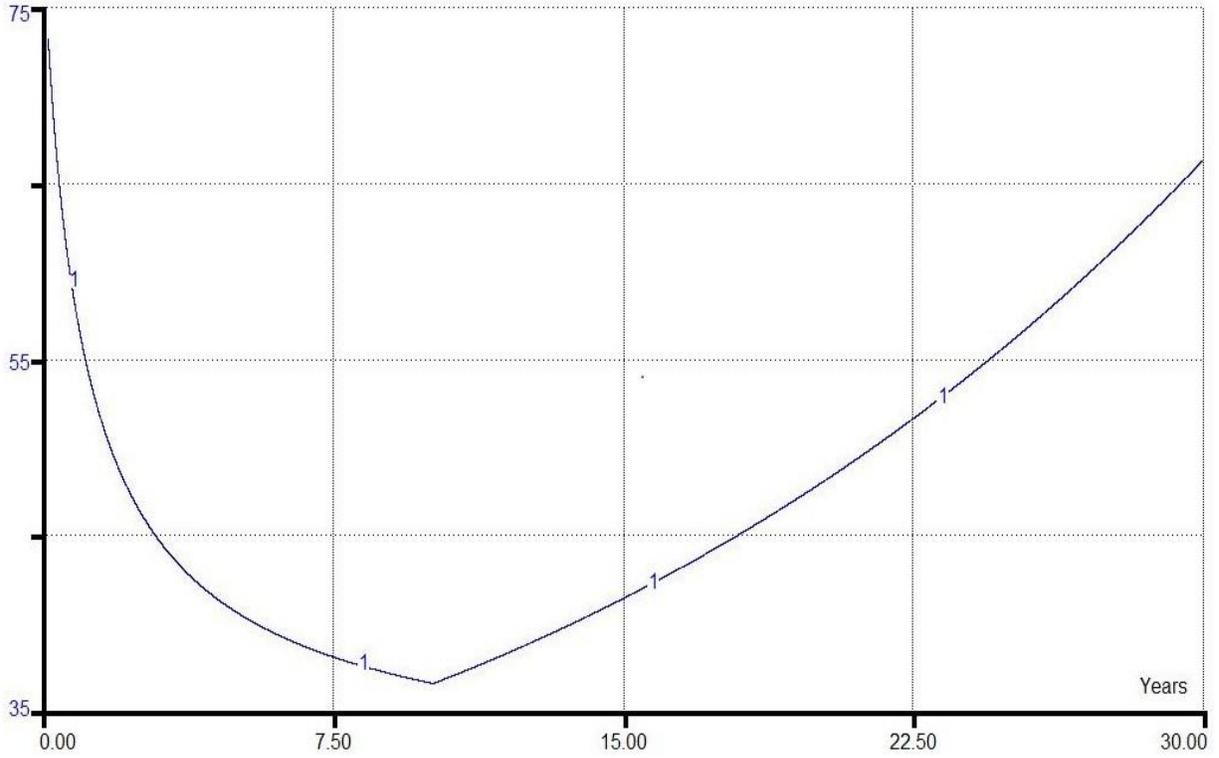


Figure-12: Unit Cost

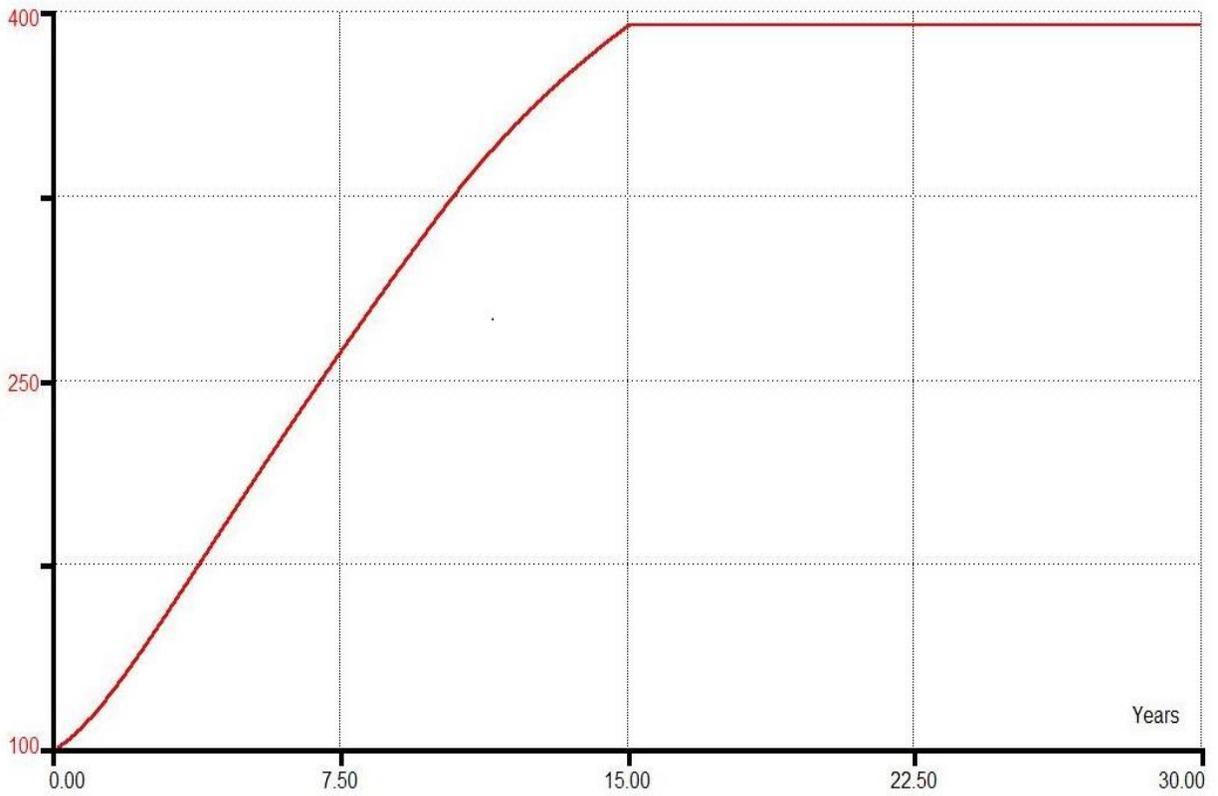


Figure-13: Product Quality

System Dynamics Model for Firm

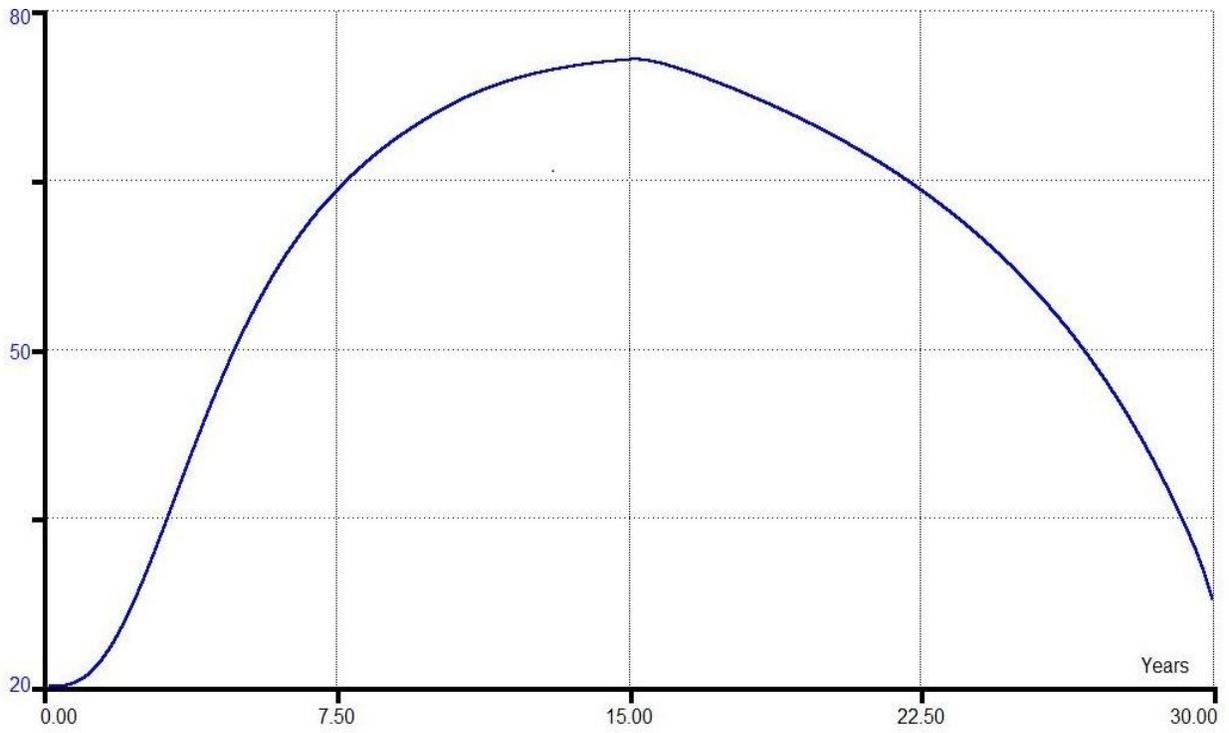


Figure-14: Market Share

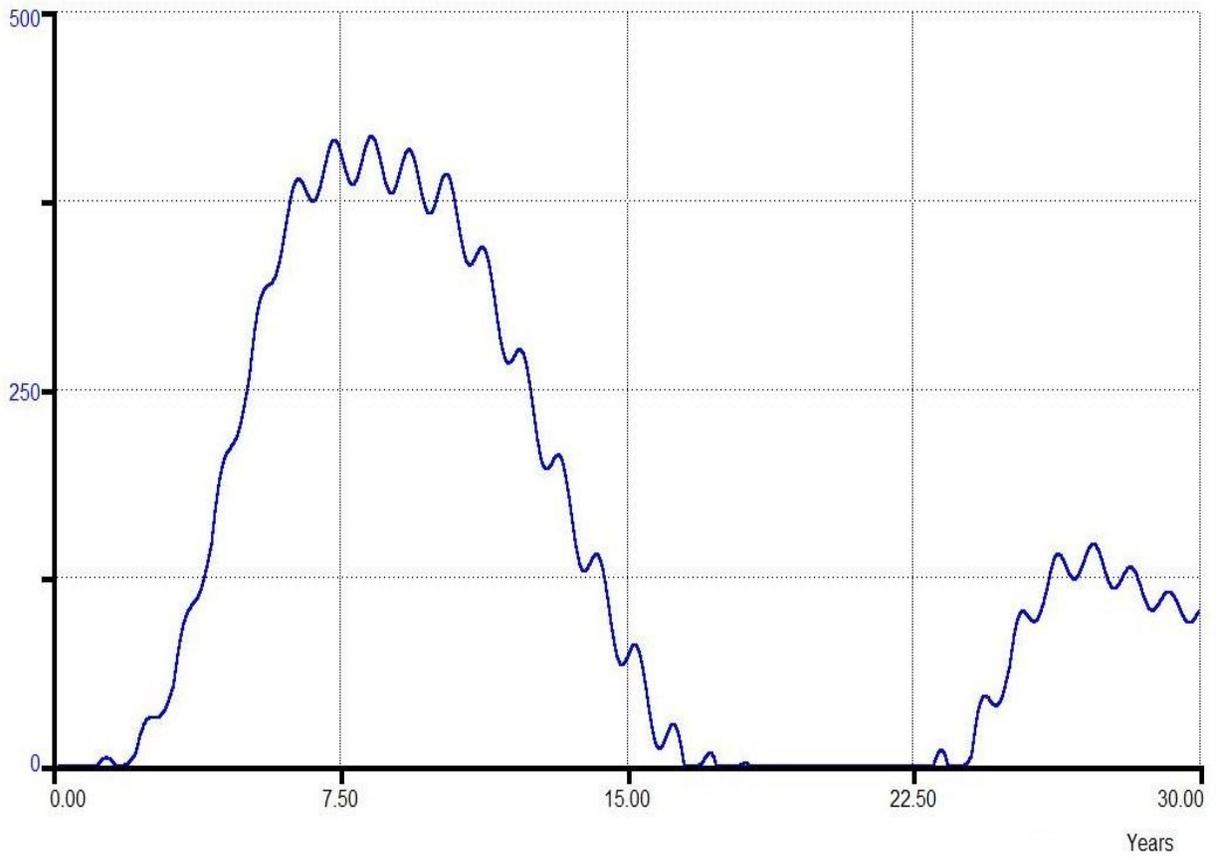


Figure-15: Inventory Level

5. Conclusion

This paper develops and uses a system dynamics model to simulate a typical firm's internal system, measuring and predicting the cumulative impacts of various managerial policies on the long-term financial performance. Alongside, this model estimates the short-term and long-term effects of various managerial policies and classic decisions involved in running a typical corporation. To this end, we employed the principles of financial accounting system along with the policies governing corporate financial situation to model the firm's financial subsystem. Then we extended it to include firm's operational and organizational processes having financial consequences. The stemmed model consists of many financial and nonfinancial stock and flow variables. One might partition this holistic model of the firm into four major subsystems according to the famous BSC approach. The system dynamics model suggested by this paper provides a systematic approach alongside a simulation method for strategic management and corporate planning in real firms. However, our analysis is only a first step, and this methodology should be used as a baseline to build more elaborate and customized models case by case.

Our model is rather unrestricted due to a small number of assumptions. Hence, empirical research would be welcome to determine functions and parameters for specific situations. In each situation, all the parameter values need to be determined through suitable statistical analysis. Especially it is important to establish well-designed policies and understand their relation with the firm's profit. Managers have to rely on the information contained within the system for their strategies and policies. In this way, a lot of essential information could be derived from the stocks within the dynamic system, for better management practice. For instance, a discrepancy between inventory and expected sales could be an important source of information for better production management. Moreover, financial ratios such as liquidity ratios, asset ratios, profitability ratios and leverage ratios extract the important parts of the available information.

BSC implies that, of the thousands of observable variables and their interrelations, only a few key performance indicators can be sufficient in determining overall system behavior. This idea of only a few indicators is very attractive. Nevertheless, how can one find the right ones? Do they work in the same direction or counteract each other? Which ones are more important? In fact, different aspects and functions of the organization are interrelated and one cannot improve one area without influencing other areas as well. The System Dynamics approach helps to overcome some of the limitations of BSC.

In this methodology, we try to simulate and evaluate different *managerial policies* and *decision rules*, not instant decisions for contingencies. In fact, we did not develop a management flight simulator, but rather a *management autopilot simulator* in order to assess and compare different autopilots and decide which one always works better for us. In short, our objective is to find the best policies as some functions of time, indicators, and other available information. So instead of making decisions case by case, we develop rules for decisions in the organization. This approach can decrease the workload of the managers as well as their power in the organization.

Appendix: *iThink*® code

Total_PV = Payoff__PV+Asset_less_Debt/(1+ rS)^TIME

Payoff__PV(t) = Payoff__PV(t - dt) + (PV__Div) * dt

INIT Payoff__PV = 0

INFLOWS:

PV__Div = Dividends/(1+ rS)^TIME

Debt(t) = Debt(t - dt) + (Interest + Debt_issue - Interest_Payment) * dt

INIT Debt = 1017

INFLOWS:

Interest = Debt*Continuous__Interest_Rate

Debt_issue = 2000/Debt_to_Equity_Ratio

OUTFLOWS:

Interest_Payment = MIN(Continuous__Interest_Rate*Debt,EBIT)

Equity(t) = Equity(t - dt) + (Retention) * dt

INIT Equity = Asset_less_Debt

INFLOWS:

Retention = PULSE(1, 1,1)*min(Net_Income*RetentionRatio,Net_Income)

Debt_to_Equity_Ratio = Debt/Asset_less_Debt

Asset_less_Debt = Fixed_Asset + Cash - Debt

Cash(t) = Cash(t - dt) + (Cash_Added - Investment - Payments) * dt

INIT Cash = 707

INFLOWS:

Cash_Added = Depreciation+EBT+Cash_Borrowed

OUTFLOWS:

Investment = PULSE(Cash*Capital__Budgeting,1.01,1)

Payments = Dividends + Tax + General_Expenses

Cash_Borrowed = Debt_issue + Interest- Interest_Payment

Fixed_Asset(t) = Fixed_Asset(t - dt) + (Investment - Depreciation) * dt

INIT Fixed_Asset = 1035

INFLOWS:

Investment = PULSE(Cash*Capital__Budgeting,1.01,1)

OUTFLOWS:

Depreciation = Depreciation_Rate*Fixed_Asset

System Dynamics Model for Firm

$Net_Income(t) = Net_Income(t - dt) + (EBT - Dividends - Retention - Tax) * dt$

INIT Net_Income = 0

INFLOWS:

EBT = EBIT-Interest

OUTFLOWS:

$Dividends = PULSE(1,1,1)*max(Net_Income*(1-RetentionRatio),0)$

$Retention = PULSE(1,1,1)*min(Net_Income*RetentionRatio,Net_Income)$

$Tax = PULSE(1,0.99,1)*Tax_Rate*Net_Income$

$EBIT = Gross_Profit + Cash * Continuous_Interest_Rate - Depreciation - General_Expenses$

$General_Expenses = Fixed_Administrative_Costs + Advertise_Budget + Training_Budget + R\&D_Budget + Compensation_Budget + Process_Budget + Inventory_Costs$

$Gross_Profit = Revenue - Variable_Costs$

$Revenue = Price * Sales$

$Variable_Costs = Sales * Unit_Cost$

$Unit_Cost = Controllable_Costs + Inevitable_Costs$

$Inventory(t) = Inventory(t - dt) + (Production - Sales) * dt$

INIT Inventory = 0

INFLOWS:

$Production = Production_Capacity - Inventory$

OUTFLOWS:

$Sales = Market_Size * Market_Share / 100$

$Production_Capacity = Productivity * Fixed_Asset / 100$

$Market_Size(t) = Market_Size(t - dt) + (Increase_in_Demand - Substitution) * dt$

INIT Market_Size = 113.1

INFLOWS:

Increase_in_Demand = 20

OUTFLOWS:

Substitution = 10

$Market_Share(t) = Market_Share(t - dt) + (Marketing + Satisfaction - Competition) * dt$

INIT Market_Share = 20

INFLOWS:

$Marketing = Advertise_Budget * (100 - Market_Share) / 400$

$Satisfaction = (Quality - Standard_Quality) - ABS(Quality - Standard_Quality) * Market_Share / 100$

OUTFLOWS:

$Competition = Market_Share * Agressiveness$

$Quality(t) = Quality(t - dt) + (Improvement) * dt$

INIT Quality = 100

INFLOWS:

$Improvement = Productivity * Process_Budget / Quality * 10$

$Productivity = HR_Motive * HR_Skills * Techno$

System Dynamics Model for Firm

$HR_Motive(t) = HR_Motive(t - dt) + (Motivation - Depression) * dt$

INIT HR_Motive = 1

INFLOWS:

$Motivation = Compensation_Budget * Compensation_Effectiveness / HR_Motive$

OUTFLOWS:

$Depression = Depression_Rate * HR_Motive$

$HR_Skills(t) = HR_Skills(t - dt) + (Training - Skills_lost) * dt$

INIT HR_Skills = 1

INFLOWS:

$Training = Training_Budget * Training_Effectiveness / HR_Skills$

OUTFLOWS:

$Skills_lost = Replacement_Rate * HR_Skills$

$Techno(t) = Techno(t - dt) + (R\&D) * dt$

INIT Techno = 1

INFLOWS:

$R\&D = R\&D_Budget * R\&D_Effectiveness / Techno$

$Controllable_Costs = 60 / \text{SQRT}(Productivity)$

$Advertize_Budget = 50$

$Agressiveness = 0.5$

$Compensation_Effectiveness = 1/50$

$Compensation_Budget = 50$

$Continuous_Interest_Rate = \text{EXP}(0.1) - 1$

$Depreciation_Rate = 0.05$

$Depression_Rate = 1/5$

$Fixed_Administrative_Costs = 27$

$Inevitable_Costs = 13.17$

$Inventory_Costs = Inventory * 0.01$

$Price = 100$

$Process_Budget = 100 - \text{STEP}(100, 15)$

$R\&D_Budget = 50$

$R\&D_Effectiveness = 1/1000$

$Replacement_Rate = 1/10$

$rS = .20$

$Standard_Quality = \text{RAMP}(1) * 10 + 100$

$Tax_Rate = .34$

$Training_Budget = 50 - \text{step}(50, 10)$

$Training_Effectiveness = 1/100$

$Capital_Budgeting = \text{GRAPH}(TIME) : \{Investment Policy\}$

$RetentionRatio = \text{GRAPH}(TIME) : \{Dividend Policy\}$

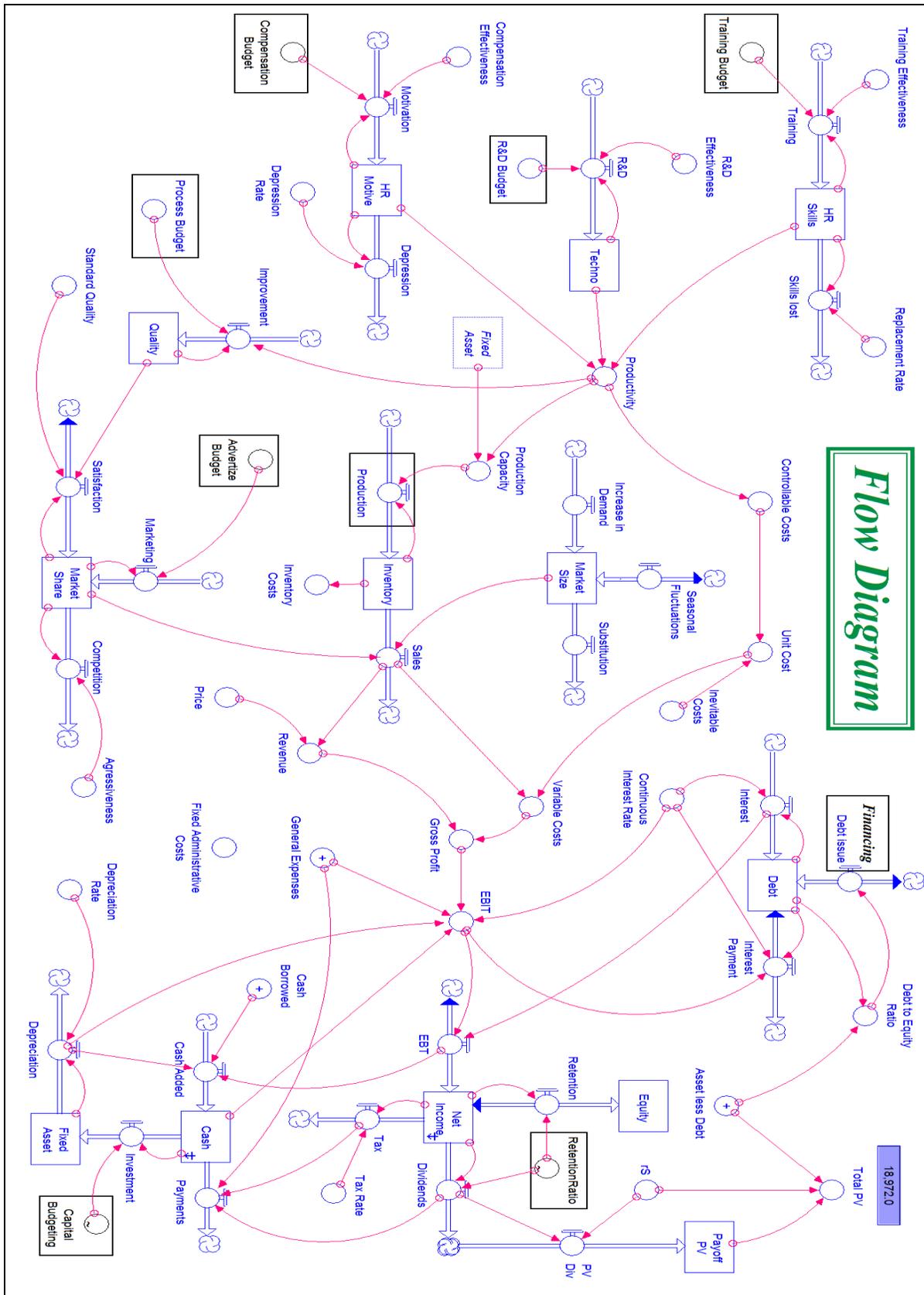


Figure-4: Complete Flow Diagram of the System Dynamics Model

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