A System Approach for Estimating Corrosion Incidence to the Economy of a Nation

Ricardo Sotaquirá G, Jorge H Panqueva A and Hugo H Andrade S
SIMONResearch Group
Systems Engineering School
Industrial University of Santander
Bucaramanga (Santander), Colombia
Mail: A.A. 678 Fax: 76 350540

Abstract

This paper presents a model in System Dynamics to estimate the economic incidence of the corrosion in the economy of a nation, in particular the Colombian case is studied. For the construction of the model, the Input-Output Analysis methodology is also used. The model disaggregates the national economy in economic sectors and allows for each one, to get their corrosion costs, and to estimate the economic benefit of control policies.

The simulation results, obtained through the EVOLUTION for Windows software, indicate that corrosion cost in Colombia is about a 2.35% of its GIP (Gross Internal Product), $US 1.250 million of dollars for 1993, approximately. This model allowed to evaluate the effects of a control policy of the corrosion , that according to the results, would induce at middle term an annual saving over the $US 125 million. These results have sustained the creation of a national entity for the investigation and technical assistance on the corrosion in Colombia.

A System Approach for Estimating Corrosion Incidence to the Economy of a Nation

Introduction

The corrosion is the deterioration of a substance (generally a metal) on account of its interaction with the environment. The corrosion is one of the technological problems that affect more the economy of a country. Particularly Colombia is found currently in a process of economic internationalization and industrial reconversion, that makes evident the need of approaching the economic implications of that problem.

The National Bureau of Standards (Bennet 1978), accomplished a study for estimating the annual corrosion cost in United States. Its result was a value of 4.2% of the GNP (Gross National Product), more than $US 70.000 million in 1978. The present study, is the first one carried out in Colombia to evaluate how much costs to the country the problem of the corrosion.

Though the corrosion can not be totally eliminated, it is possible to reduce its incidence through control policies. Then, appears a second question: how much can save the country, to short, middle and long term, with a given control policy of the corrosion?.

To answer the outlined questions, it was proposed the construction of a System Dynamics model, complemented with Input-Output Analysis, to estimate the corrosion costs for Colombia and the economic impact that can be obtained by mean of the investment in control.

The corrosion and its economic implications

The corrosion affects every agent of the economic process, both producers and consumers. On account of it, capital, energy, and other resources are wasted, on problems like: losses of products, pollution in the environment, maintenance and equipment repairment, plant capacity in excess, equipment and constructions replacement and industrial safety risks, including losses of human lives.

There are not much efforts accomplished by national companies to control their corrosion problems, as well as the investment in scientific and technical infrastructure to provide solutions for this situation.

In some countries studies have been accomplished, at national level, to estimate the corrosion costs: United States (Bennet 1978), United Kingdom (Hoar 1976), Australia and Spain, among other. None of these studies analyze the economic impact of applying corrosion controls, as the present model does.

Feedback structure

The target problem, the corrosion, is studied in its economic side, that is, embedded in the Colombian Economy. Consequently it is analyzed the effect of a phenomenon: the corrosion, that is verified inside a system: the National Economy. This system can be disaggregated in economic sectors: the subsystems, which keep close relationships by virtue of an intricate net of commercial transactions between them. In the model, the Colombian economy is disaggregated in nine economic sectors, according to two criteria: a greater component in the Colombian GIP, and the possibility of applying control techniques at short and middle term. The most important sectors for the study are: agricultural, mining, oil refining, machinery and metallic products, construction and services of electricity, gas and water.

Figure 1 shows the manner as the corrosion impacts in the economic sectors and propagates its incidence to whole economy. In the figure appear two any economic sectors. One of them has corrosion problems that cause an increase in its production costs (more exactly in its added value) and the consequent increase in the sale prices of its products. These products are sold to the other sector then its production costs and its sale prices are increased. When the last sector sells its products to the first one, the feedback loop is closed. The feedback loop is consequence of the relationships of economic exchange among the sectors; each exchange implies a feedback loop in the economic system, generating a complex feedback structure.

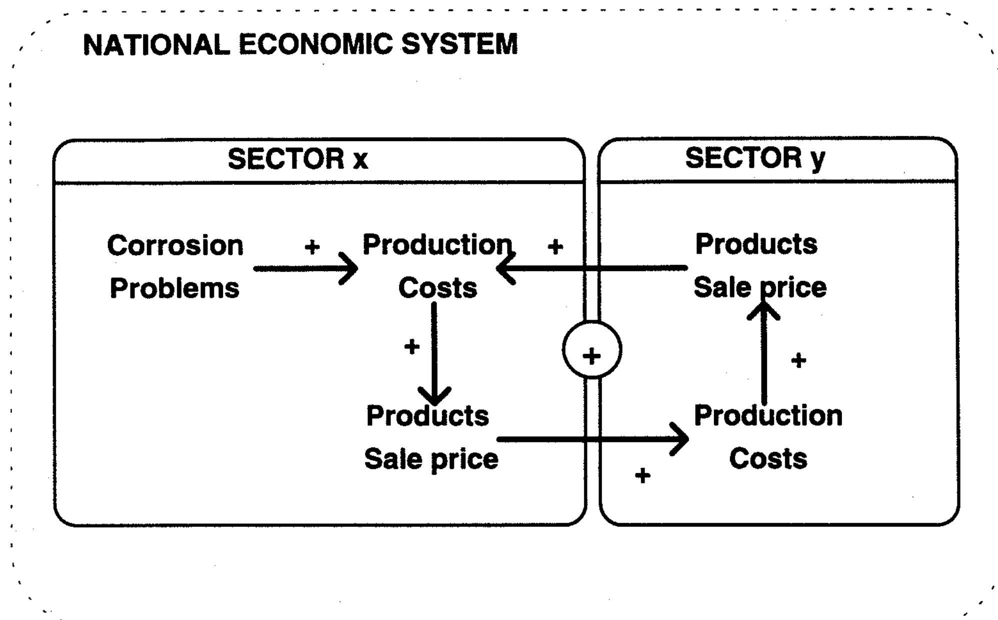

Fig. 1. Feedback structure of the economic exchange of two sectors inside to the national economic system.

To simplify its representation in the model were introduced two concepts as it is illustrated in the Figure 2: direct costs and indirect costs. The first ones, direct, are caused to a sector by its local problems, and the second ones, indirect, are the effect on a sector of the corrosion problems of the other sectors, by means of the already explained feedback loops. So that the total corrosion costs for a nation are greater than the sum of the costs by local corrosion problems in each economic sector, which emphasizes the synergy of the national economic system.

To formalize the causal relationship of the corrosion problems in the national economy, on the indirect costs in a sector, it is necessary to use a complementary modeling methodology: the Input-Output analysis, which is presented in the following section.

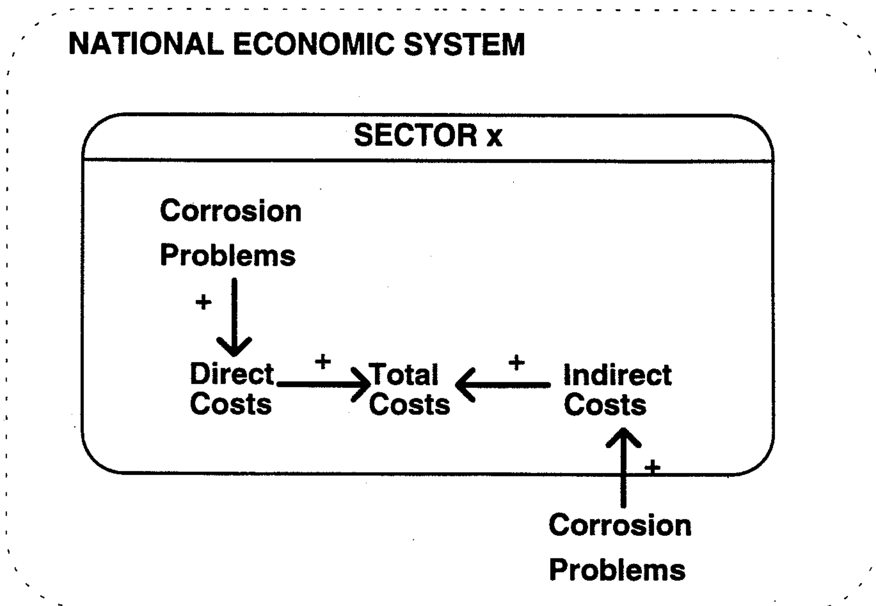

Fig. 2. Direct and indirect corrosion costs of an economic sector.

General structure of the model

Figure 3 shows, only for one sector, the three modules that compose the System Dynamics model: corrosion control module, module of estimation of the indirect effect and module of conversion to nominal value.

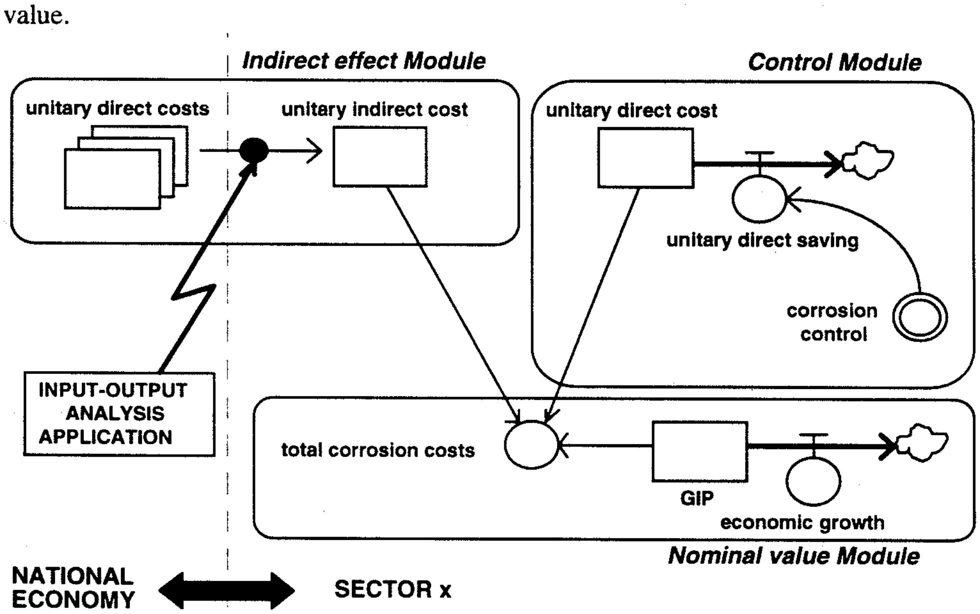

Fig. 3. Modules that compose the System Dynamics model, for an economic sector.

The corrosion control module is composed by the stock named unitary direct cost (udc), that indicates fo: any sector the direct cost due to the corrosion by each dollar (monetary unity) of its gross internal product (GIP); the corrosion control in the sector, which i: considered in the model an exogenous element, causes a decrease in the unitary direct cost, through a flow named unitary direct saving. The control is measured like the percentage of the corrosion in the sector that can be reduced in a given period applying certain control actions.

The disaggregation in economic sectors made to the model, multiplies the number of its elements. To simplify its mathematical representation, every variable is a vector, which contains information of the nine economic sectors.

The module of estimation of the indirect effect, has the purpose of quantifying the influence of the unitary direct costs stock on the unitary indirect cost stock of a sector in particular. To do this, it is used the Input-Output Analysis (methodology of algebraic structural character of common use for the macroeconomics models construction) (Lora 1991). By means of it, it is possible to represent quantitatively the feedback structure of the national economic system, making use of the input-output matrix, which contains in each cell, the value of the transactions between two sectors of the economy for a given period, generally one year. That is, each feedback loop presented in the Figure 1, becomes a cell of the input-output matrix.

Applying an Input-Output Analysis procedure is possible to obtain an index for quantifying the variation in the added value of each sector, as consequence of a corrosion control policy. This index is function of the unitary direct costs and function of two data derived from the input-outuput matrix: the Leontief inverse matrix and the added value coefficient. By means of this index is affected a saving flow that reduces the unitary indirect costs stock of each sector. The Figure 3 shows the relation between direct costs and indirect cost, but the input-output details are hidden, for simplifying.

Finally, the module of conversion to nominal value permits to transform the unitary costs to costs into monetary unities, in this case into dollars. For this is necessary to multiply the unitary costs by the GIP (gross internal product) of each sector. GIP is a stock affected by the economic growth, considerate exogenous to the model.

In summary the model is composed by 18 variables and parameters, vectors and matrices, and by 1: equations, in matrix algebra. With the model can be estimated the unitary corrosion costs and dollar corrosion cost, and by means of the variation of the cost stocks can be determined the saving a consequence of a control policy.

Results

The simulation of the model was accomplished in a microcomputer, using Evolution 1.0, window software tool for System Dynamics Modeling, developed by the SIMON Research Group (Investigation Group in system simulation and modeling) of the Industrial University of Santander (Gélvez 1994).

The simulation scenario is defined by: the parameters corresponding to the Input-Output Analysis, the initial values of the direct corrosion costs and the control policy that is pretended to evaluate.

For simulating the Colombian case, the Input-Output parameters, that is, input-output matrix, Leontief inverse matrix and added value coefficient, are based on National Accounts information of the Colombian National Administrative Department of Statistics, for 1992 year (DANE 1992).

The initial values of direct corrosion costs were derived from the results of the study of the National Bureau of Standards (Bennet 1978), corrected in this work for the Colombian case (Sotaquirá 1994), through the capital-product relation (Mueller 1971), (Lora 1988).

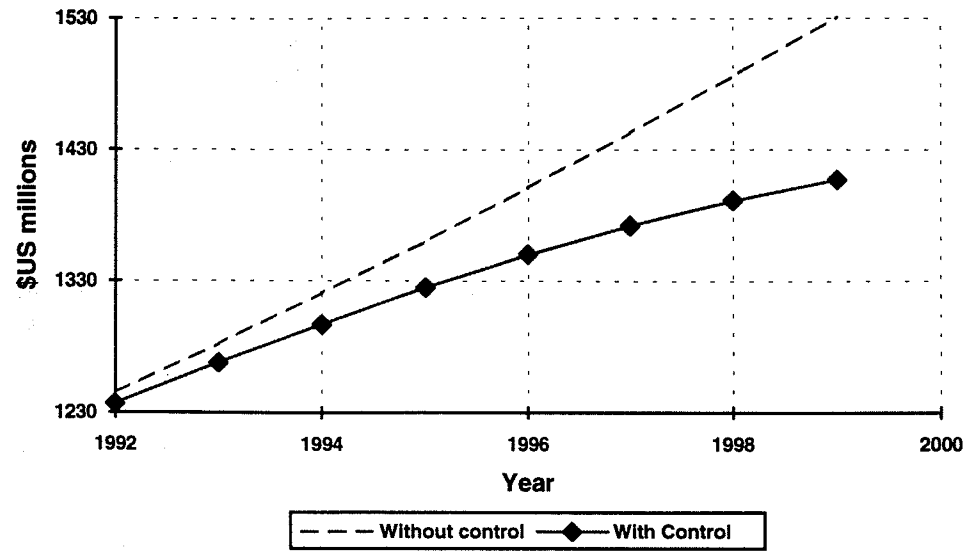

Fig. 4. Behaviour of the Colombian corrosion cost. Basic behaviour and behaviour influenced by the corrosion control policy.

The evaluated control policy consists in the application of corrosion control technology, actually available, in an eight years interval, on six economic sectors of greater interest: agricultural, mining, oil refining, machinery and metallic products, construction and services of electricity, gas and water.

The simulation was accomplished for a simulation period from 1992 until 1999, within which the Input-Output parameters can be considered yet valid for the country.

Figure 4 compares the basic behaviour (without control) of the Colombian corrosion cost against the result of introducing the previous control policy. The basic behaviour grows with constant slope because depends on the national economic growth, that was considered constant in this simulation. While the behaviour of the cost influenced by the control, is exponentially attenuated. This exponential character is due to that the direct cost is a stock, that decreases by virtue of the influence of a growing linear function of corrosion control, on its saving flow. Figure 4 shows that the corrosion costs at 1999 would be $US 1.520 million without control, and $US 1.390 with control, that is, between 2.35% and 2.15% of the GIP, respectively. This values are found within the range reported by international studies: between 2% and 4% of the GIP (Morcillo 1991).

The difference between the two cost behaviour curves results in the saving obtained with the control policy and appears in the Figure 5. With this policy would be possible to save from $US 55 annual million in the short term, until $US 125 annual million in the middle term. Though the saving growth is exponential, it has a limit that will be reached when a generalized use of the better available

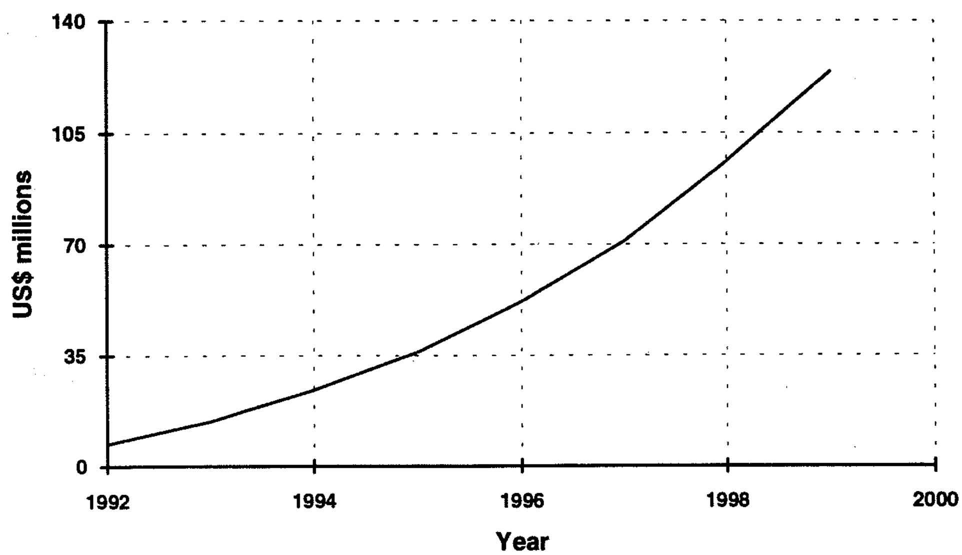

Fig. 5. Saving obtained with the application of the control corrosion policy.

technology for the corrosion control be applied. Any subsequent saving would depend on new control technologies. Consequently in the long term the saving curve attenuates its growth until a stabilized stage, resulting in a S shape.

Conclusions

The results, obtained with the simulation of the model, served as a valid scientific argument to sustain the creation of a national entity, the Corporation for the Investigation of the Corrosion, and consequently contributed to attend to the solution of an important problem for Colombia and for any other nation.

The combination made of the methodologies: System dynamics and Input-Output Analysis, uses their respective strengths complementing them, and indicates new fields of application for both approaches.

The general character of the model permits that, in a future, it could be applied to estimate the corrosion problem in other systems (for example, other country or a given economic sector), and even that it could be adapted to evaluate the impact of other phenomena on the economy of a nation.

References

Aracil, Javier. 1983. Introduction to the System Dynamics. Spain: Alianza Editorial.

Bennet, L.H. et al. 1978. Economics effects of Metallic Corrosion in the United States. Congress by the National Bureau of Standards. United States.

Bertoglio, Oscar. 1987. Introduction to the General Systems Theory. Mexico: Limusa.

DANE (National Administrative Department of Statistics). 1993. National Accounts of Colombia. Magazine DANE (1970-1992). Colombia.

DNP (Planning National Department). 1992.Corporation for the investigation of the corrosion. Bank of national investment projects. Colombia.

Gélvez P., Lilia N., Sotaquirá G., Ricardo, Muskus M., Zandy C., Díaz D., Juan C. 1994. Technical Guide and User Manual of Evolution for Windows. Colombia: SIMON Research Group, Industrial University of Santander.

Hoar, T.P. et al. 1976. Corrosion - Cost and Control. Economics of Corrosion Control -Autumn Review Course. United Kingdom.

Lora, Eduardo. 1988. Introduction to the Colombian macroeconomics. Colombia: Tercer mundo - Fedesarrollo.

Lora, Eduardo. 1991. Technical of Economic measurement: methodology and applications in Colombia. Colombia: Tercer mundo - Fedesarrollo.

Martínez, Silvio and Requena, Alberto. 1987. Systems dynamics, Vol. I and II. Spain: Alianza Editorial.

Morcillo Linares, Manuel. 1991. Personal interview. Researcher of the National Centre of Metallurgical Investigations in Madrid. Colombia.

Muskus M., Zandy C. and Gélvez P. Lilia N. 1994. Construction and simulation of a model for the control of the Leishmaniasis under an systemic approach. Systems Engineering Thesis. Colombia: Industrial University of Santander.

Mueller, M.G. 1971. Macroeconomics readings. USA.

National Association of Corrosion Engineers. 1984. Corrosion Basics: An Introduction. USA: NACE.

Sotaquirá Gutiérrez, Ricardo. Panqueva, Jorge. Andrade, Hugo. 1994. Incidence of the corrosion on the national economy. Systems Engineering Thesis. Colombia: Industrial University of Santander.