

ANALYZING THE ECONOMIC SUSTAINABILITY OF SMALL SCALE AGROINDUSTRIAL ENTERPRISES: A SYSTEM DYNAMICS APPROACH

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ABSTRACT – Governmental programs aiming at the implementation of small scale agroindustrial firms have been generally characterized by high enterprise failure rates. This work argues that in order to promote economic sustainability, project evaluation must take into account not only traditional profitability, uncertainty and risk indicators, but also aspects related to the dynamics of raw material procurement, processing and product distribution. A system dynamics approach is proposed as a complement or alternative to traditional agroindustrial project analysis. The approach is illustrated by the development of a prototype simulation model for a small scale cheese processing plant. The model was applied to evaluate alternative scenarios for cheese plant operations. Results suggest that the proposed approach could be an important addition to the set of tools used for project evaluation.

Keywords: project evaluation, agroindustry, system dynamics.

ANÁLISE DA SUSTENTABILIDADE ECONÔMICA DE AGROINDÚSTRIAS DE PEQUENO PORTE: UMA ABORDAGEM DA DINÂMICA DE SISTEMAS

RESUMO – Programas governamentais visando a implantação e desenvolvimento de agroindústrias de pequeno porte tem sido caracterizadas por uma alta taxa de insucesso. Este trabalho discute que, visando promover a sustentabilidade econômica, a avaliação do projeto deve levar em consideração não apenas os indicadores tradicionais de riscos, incertezas e lucratividade, mas também os aspectos relacionados à dinâmica da aquisição de material-

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prima, do processamento e da distribuição de produtos. A abordagem de Dinâmica de Sistemas é proposta neste artigo como complementar ou alternativa à tradicional técnica de análise de projetos agroindustriais. Esta proposta é apresentada por meio da modelagem e simulação de um protótipo de simulação de uma planta de processamento de queijo de pequena escala. O simulador foi aplicado para avaliar cenários alternativos para as operações da planta. Os resultados sugerem que esta abordagem pode ser uma importante contribuição para o conjunto de ferramentas utilizadas para análise de projetos.

Palavras-chave: avaliação de projetos, agroindústria, dinâmica de sistemas.

1 INTRODUCTION

Aiming to foster socio-economic development in rural areas, a number of programs encouraging the implementation of small-scale agroindustrial enterprises have been designed and established in Brazil. Typically, such enterprises have less than 20 employees and utilize simple, non-capital intensive processes to aggregate value to agricultural raw materials. Despite the financial incentives and support services provided, the economic sustainability of the promoted investments has been rather discouraging - the failure rate of new small-scale agroindustrial enterprises has been extremely high (VIEIRA, 1998). Overall, approximately 50% of the new industrial enterprises in Brazil fail before completing their third year, according to SEBRAE-SP/FIPE (1998, 1999). Ferraz and Silva (2003) found for the smallest agroindustrial firms in the country that only 24% survive after the first five years of activity.

Evidence revised by Lourenzani e Silva (2003) shows the development and sustainability of an agroindustrial project depends, to a large extent, on a more sophisticated entrepreneurial conception than the one that prevails in the current promotion programs. In other words, there is a need for

a better capacity to evaluate and analyze opportunities, risks and uncertainties involved thereof. As such, it is here argued that the effectiveness of small scale agroindustrial development programs and the success of the new enterprises they promote may plausibly be enhanced through a more sophisticated design of business programs and plans, so that the variables that may pose a threat to sustainability are duly identified and evaluated systemically.

Typically, project analysis is performed through a set of methods, supported by basic economic principles, which are applied in order to evaluate and compare alternative investment opportunities (AZEVEDO-FILHO, 1995). Several such methods are described in the literature, ranging from the simple perception of the decision maker about the prospects of his business to the application of sophisticated mathematical models. Most have, as a preliminary phase, the estimation of costs and revenues which will occur over time. A financial timetable of the project and its respective cash flow are then generated with basis on these estimates, with the latter being the main input to the analysis process.

The computation of financial indicators³ associated to the economic performance of a project allows expressing directly, through numerical values, its financial feasibility, thus simplifying an otherwise complex analysis situation. These indicators will allow the investor to consider evaluation aspects which a simple cash flow monitoring would not reveal.

Brown (1995) states that the methodology utilized for the financial analysis of agroindustrial projects is similar to that applied to any other enterprise - the criteria validating the investments and the decision-making process are the same. However, both Brown (1995) and Austin (1992) point out that the agroindustrial activity displays significant particular characteristics that affect the structure and financial performance of that type of enterprise, and consequently, their viability. These comprise long production cycles, seasonal markets, short harvest and processing periods, perishable raw materials and qualitative variability of inputs.

Considering that traditional project analysts make use of deterministic assumptions about technical and economic aspects in a quite generalized way, the validation of their results, particularly in the case of an agroindustrial project, can be questioned. Assumptions on raw material yields and supply regularity, labor usage, input costs and market prices, among others, are typi-

cally deterministic and, although useful for evaluations under practical conditions, they can be a strong simplification for most types of agroindustries. Moreover, since there is tendency for an analyst to work with optimistic assumptions, project analysis frequently overestimates the economic performance of the investment project (AZEVEDO-FILHO, 1995).

In order to minimize these problems, some methods consider uncertainties and risks in project analysis, characterizing the so-called sensitivity and risk analyses (HARDAKER *et al.*, 1997.) However, aspects related to the interdependence of factors characterizing the enterprise, along with the time delays that exist between an action and its reaction, are not taken into account in these approaches. Traditional analysis also fails to consider feedback effects inherent to agroindustrial systems.

To evaluate the major sources of uncertainties associated to agroindustrial enterprises, Lourenzani and Silva (2003) carried out sensitivity analyses on 15 small scale projects. The study clearly showed that financial results have a strong dependence on a small set of assumptions raised in the definition of revenues and costs. It was observed that results are directly influenced by variables associated with the definition of product demand and raw material supply, normally not considered in the traditional evaluations. Another important factor, market insertion, influences the latter two variables. Based on these considerations, it was suggested that the feasibility study of an agroindustrial project should not only have a strictly financial approach but also take into

³ A financial indicator of an investment project performance is a figure calculated with basis on its cash flow in order to measure a particular dimension of the quality of the investment (AZEVEDO-FILHO, 1995). Typical indicators are the internal rate of return, net present value and payback period.

account the systemic relations inherent to its structure and mode of operation.

Systems analysis (SENGE, 1990) implies that a project feasibility study must focus not only on financial evaluation aspects, but also on an operational and managerial assessment of the enterprise and of its

insertion in an institutional and competitive environment. Following this “system thinking” principle, the understanding of a prospective business is reached through the analysis of the interactions among its components, i.e., of the system as a whole, as depicted in Figure 1.

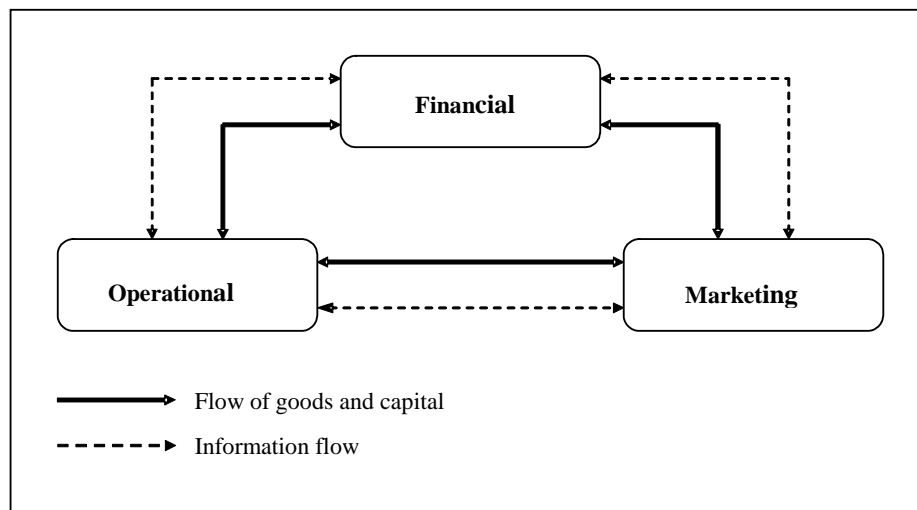


Figure 1. Systems view of the components of an agroindustrial enterprise.

In the diagram, the double arrows suggest the importance of feedbacks among the system components. While the human mind is perfectly capable of visualizing the “loops” shown in Figure 1, it is much harder to mentally evaluate the results of changes in any particular element within such a complex structure (MORECROFT; ACKERE, sd). The Systems Dynamics methodology allows this sort of evaluation of dynamic implications in non-linear systems, by designing, processing and interpreting simulation models. (RICHARDSON, 1991).

Within this context, the main objective of this work is to propose a System Dy-

namics approach as a viable complement to traditional agroindustrial project analysis. The approach is exemplified by a case study involving the development and use of a prototype simulation model of a small scale cheese processing plant project.

2 SYSTEM DYNAMICS

The proposal of system dynamics (SD) is to conceive, model and simulate systems characterized by interdependence of components, *feedback loops* and delays between causes and effects. The basic structure of a SD model is constituted by two compo-

nents, namely stocks and flows, which are organized in the form of cause-effect relationships that can be subject to time delays. Stocks represent variables that accumulate through time. Their level at one given point in time stems from the difference between input and output flows. Examples of stocks are the production volume of a company, the number of animals in a herd or the balance of a bank account at any given instant. The flows, on the other hand, derive from decisions or policies that interfere in a system. They are described in the form of algebraic equations. Examples of flows are sales growth rates, birth rates of a population or periodical taxes charged to a savings account. Feedback structures are present when a stock level depends of its value at previous points in time (BRAGA *et al.*, 2004).

By modeling a system through a representation of stocks, flows and policy or decision related variables, one can simulate its behavior through time by solving a system of differential equations. Through the utilization of symbolic graphical resources, the modeling and simulation of dynamic systems have been greatly simplified by the availability of specialized software (POWERSIM, 1996). With such software tools, it is possible to represent, with relative ease, the overall system structure, including its elements, causal interactions, response times, feedback loops and delay effects. It is also possible to automatically generate numerical solutions that depict the behavior of the system through any desired time frame.

Systems Dynamics (FORRESTER, 1961) has been applied to help understand and support decision making process of complex issues in several areas. Readers are

referred to Richardson (1991) and Sterman (2000), for examples of such applications. A good source for current research on the subject and its applications is the web page of the System Dynamics Society (<http://www.albany.edu/cpr/sds/>).

3 CASE STUDY

O modelo Data for model development was obtained from a cheese plant agroindustrial profile developed by Furtado *et al.* (2003). This small scale plant has a milk reception capacity of 400 liters/day. It produces two types of cheese: a hard, ripened cheese known in Brazil as “Minas Curado”, and a partly ripened variety named “Meia Cura”. Considering a 10 year planning horizon, with investments in fixed and working capital concentrated in a pre-operational period of one year and assuming full utilization of plant capacity at the first year of operations, the project has an internal rate of return of 21.7%, a break-even point of 39% and a payback period of 5 years.

3.1 Dynamic Simulation Model Development And Results

An analytical guideline presented by Austin (1992) was used to develop a logical scheme and to single out the relevant factors of the agroindustrial enterprise modeled. This allowed the identification of a number of critical issues to be considered which were represented by “influence diagrams” covering the areas of procurement, processing and distribution. Based on the systems thinking methodology (SENGE, 1990 and ANDERSON; JOHNSON, 1997)

this conceptual model was conceived to represent the operations of the prospective small scale enterprise. This model (Figure 2) expresses the interdependence among the financial, operational and marketing plant modules (Figure 1) and is the basic structure

underlying the next modeling stage. The symbols “B” and “R” in the diagram refer, respectively, to balancing (negative) and reinforcing (positive) feedback loops. Arrows indicate the direction of causality and crossed arrows represent time delays.

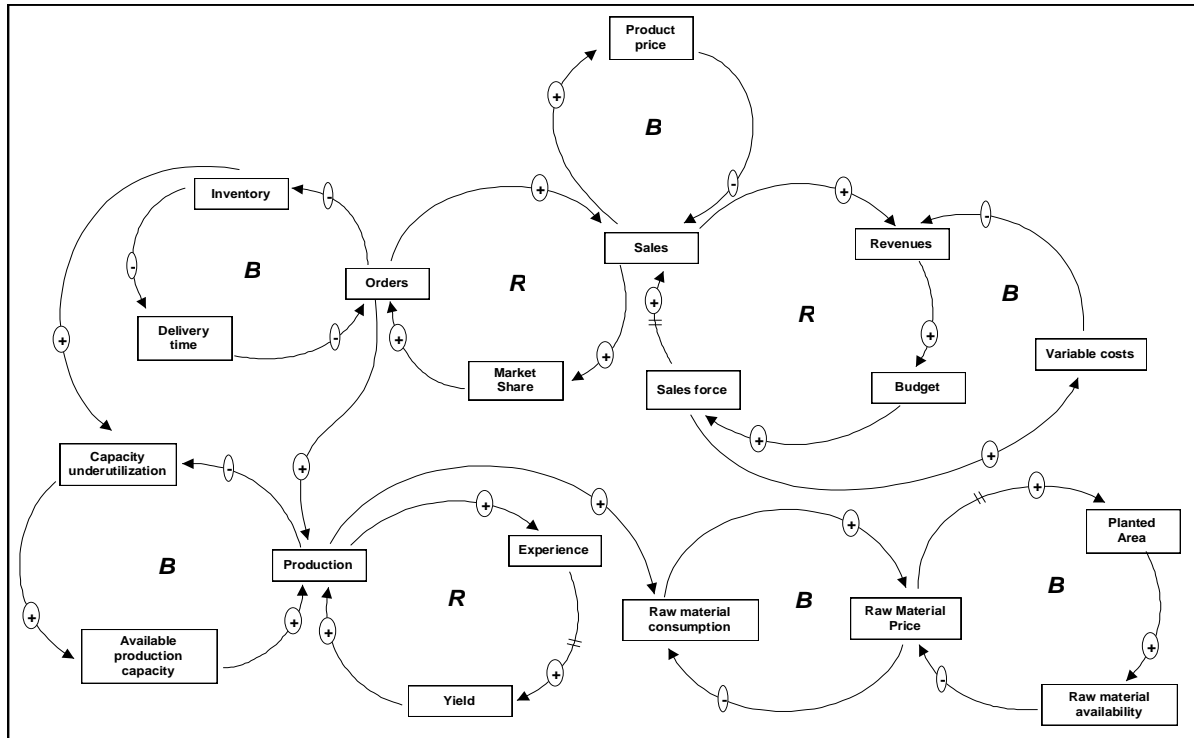


Figure 2. Influence Diagram of a small scale agro industrial enterprise system.

By examining Figure 2, we can have a general notion of the main types of loops and feedback structures associated with the enterprise system. Exemplifying, we see, on the top of the diagram, a simple, inverse relationship between product prices and sales. The level of sales influences the amount of enterprise revenues, which in turn provides more resources for the sales budget, strengthening the sales force, whose ef-

forts should eventually lead to an increased sales level. This positive loop is counterbalanced by the market share attainable by the modeled enterprise and by the augmented costs generated by the sales effort. The loop at the top left of the diagram shows that the level of product orders diminishes product inventory, which affects the delivery time – the lower the inventories, the higher the delivery time. The level of product orders

has a positive association with the production level, which is also related with variables such as the expertise of the enterprise manager, the consumption of raw material and the utilization of plant capacity. Last, the diagram depicts at its bottom right a classical relationship between supply and prices. The intricacy of the systemic relations between the three components of the agroindustrial enterprise system is thus uncovered, in the process of preparing such an influence diagram.

The conceptual model of Figure 2 was then converted into mathematical language, so as to render the description non-ambiguous. The graphical representation of

the formal model in the structure of stock and flow diagrams, illustrated in Figure 3, is used by the software POWERSIM (©1996 Powersim Corporation), adopted in the present study.

It automatically generated a corresponding system of differential equations, whose solution, also automatic, describes the behavior of the variables of interest as a function of time. In Figure 3, boxes and circles linked by double lined arrows represent respectively accumulations (stocks) and rates (flows). Auxiliary variables are depicted by the remaining circles, while the parallelograms symbolize constant values.

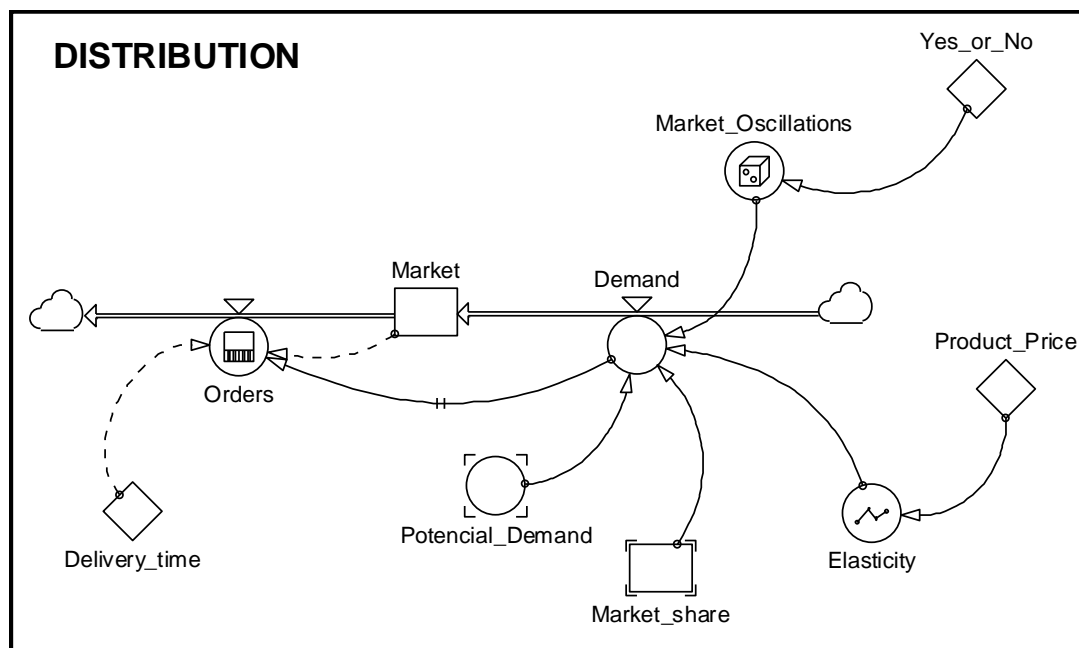


Figure 3. Formal Model representative of one operational subsystem (specifically, the distribution segment).

Figure 3 illustrates a stock and flow model characteristic of the operational subsystem simulating the cheese distribution chain. The size of the firm's market at any given time (a stock) is increased by the demand flow and reduced by the number of orders the simulated firm can meet. The flow of orders is affected by the firm's ability to be responsive, i.e., the delivery time, and indirectly by the perceived demand level (potential demand) and by the market share potentially attainable. Disturbance shocks in demand can be simulated by model user induced changes in consumer preferences (random market oscillations), product prices or demand elasticities. For simplification purposes, the variables representing the competitive environment, which influence both the market share and the potential demand, are not presented in the diagram.

Two other subsystems, encompassing respectively the procurement and processing functions, were likewise

represented by stock and flow models. Interactions of the three subsystems with the plant's competitive and institutional environments were represented by the inclusion of selected exogenous variables. Moreover, a fourth simulation subsystem was included, to represent the financial components of the plant operations. Interested readers can obtain from the authors copies of the complete model.

The resources of the SD software utilized allowed also the development of a user-friendly interface, known in the literature as a Management Flight Simulator. Its purpose is to promote learning through interactive experimentation (FORD, 1999), selecting important factors, representing them through icons, changing their values and visualizing the effects of such changes through graphics and tables. Part of the Management Flight Simulator is shown in Figure 4.

The control panel is organized into several sections:

- Competition:** Radio buttons for High, Medium, and Low.
- Agroindustrial Unit:** Radio buttons for Isolated and Networked.
- Previous experience:** Radio buttons for High, Medium, and Little.
- Producer contracts:** Radio buttons for Yes and No.
- Sales force:** Radio buttons for Aggressive, Normal, and Mild.
- Market oscillation:** Radio buttons for Yes and No.
- Growth Rates:** Four input fields, each containing the value 0,00%:
 - Milk production growth rate
 - Ripened cheese consumption growth rate
 - Half ripened cheese consumption growth rate
 - Population growth rate

Figure 4. Control Panel (Management Flight Simulator).

This type of simulation interface allows the visual presentation of parameters that can be easily changed by model users. The most relevant factors (inputs) can be configured through interactive icons (Figure 4), thus providing a “managerial laboratory” of a small scale agro industrial enterprise project. Each run of the model, with a different set of parameters, would constitute a “laboratory experiment”. Learning about the system is greatly facilitated in this fashion.

The interpretation of the dynamic simulation model must have a qualitative focus, since the methodology is not designed to predict future values of any particular variable (FORD, 1999). By simulating and interpreting scenarios, the decision-making process is supported, allowing the analyst to understand system behavior under different conditions and visualize the effects of alternative policies, before implementation. Inevitably, proper interpretation and understanding of a complex system can only occur after analyzing an array of policy simulations. Towards this end, alternative system scenarios can be proposed and simulated. To illustrate the approach followed in this study, four scenarios have been tested, namely:

- **Scenario 1:** steady-state conditions, according to the original data of the small-scale cheese processing project.
- **Scenario 2:** the only change made regarding scenario 1 was to consider a smaller

initial demand for the plant products. The intention was to assess the effects of a more realistic marketing plan at the initial plant implementation phase.

- **Scenario 3:** besides the change made in scenario 2, this case includes assumptions such as an increase in the level of competition, attribution of an average level for the entrepreneur’s previous experience and the consideration of a “normal” level for the sales effort. Assumptions regarding the existence of market demand oscillations and the inexistence of procurement contracts with milk producers were also made.
- **Scenario 4:** steady state conditions modified by the simulation of an incentive policy for small agroindustrial enterprises in the form of sale tax reduction (value added tax).

The results of these simulations, expressed by the accumulated cash flow of the project over a 10 year planning horizon, are seen in Figure 5. This variable was chosen for the analysis, for it is assumed to represent well the economic sustainability component of the enterprise. The pay-back period for each scenario is shown at the points where each line crosses the dotted line. Accumulated cash flows in Brazilian currency (“Reais”) are shown by the height of the lines at any point in time.

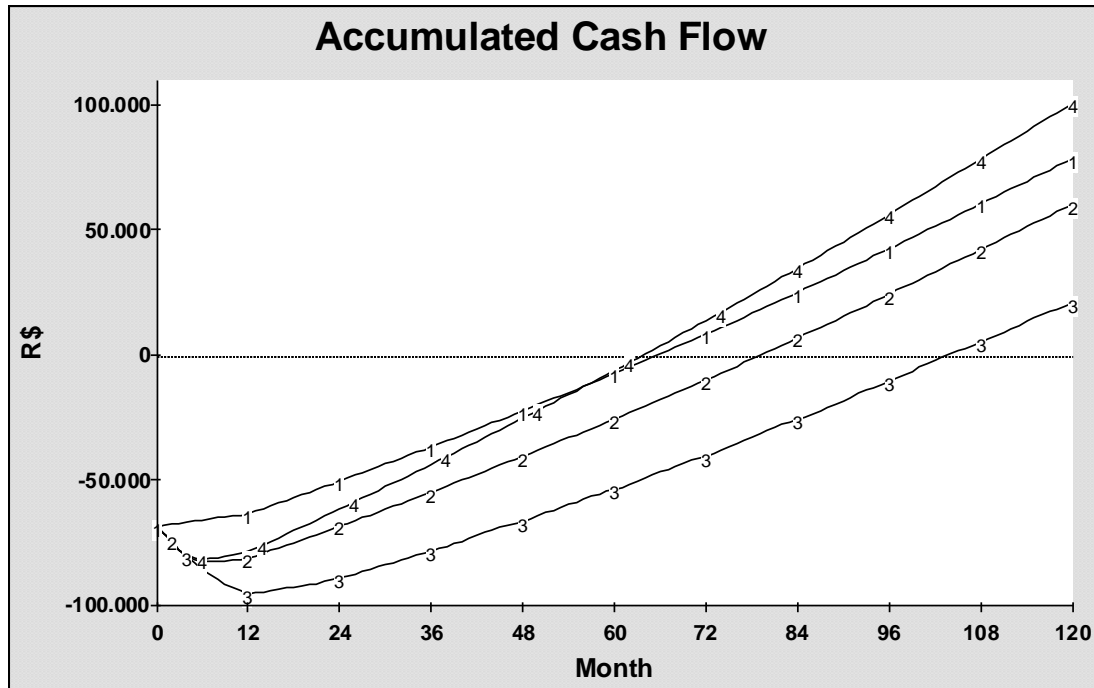


Figure 5. Comparative graphic of the accumulated cash flow in four different scenarios.

When considering scenario 2, which simulates a smaller and more realistic initial demand, it is observed that the payback period increases, relative to scenario 1. This suggests that this enterprise has a visible degree of uncertainty related to market demand. Additionally, when new assumptions regarding competition were considered (scenario 3), the negative effects were enhanced. Thus, this project is particularly affected by market conditions which, under traditional evaluations, would be considered stable and typically optimistic. Indeed, the common project analysis procedure is to consider that sales equal 100% of the total output throughout the planning horizon. When allowing for feedback effects and more realistic market conditions, the analysis uncovers

potential fragilities that should be dealt with by proper policies, if the sustainability goal is to be achieved. Scenario 4 exemplifies the effects of one such policy.

In the enterprise under study, raw materials and value added tax (VAT) account, in average, for 70% of unit costs. Assuming the adoption of a policy of incentive to small agroindustries, where the VAT of 12% is reduced by half (scenario 4), the results are the most favorable of all simulations, as seen by the lower payback period and the higher levels of accumulated positive cash flows throughout the planning horizon (Figure 5).

Other scenarios could be easily constructed by varying the parameters represented in the “management flight simu-

lator” or by changing them directly at the model structure level. Changes in structure can also be easily tested, in view of the convenient graphical model building features provided by the software tool.

4 CONCLUDING REMARKS

Although simple in its structure, the prototype simulation model described in this work can be a helpful tool to improve understanding of the complexity associated with the operations of small scale agroindustrial enterprises. This improved knowledge, in turn, can be used in order to complement and strengthen project evaluation processes and to design effective agroindustrial development support policies, thereby contributing to the reduction of enterprise failure rates.

System dynamics is a well established methodology that has been successfully applied in a wide variety of problems. Given the social and economic importance of small scale agroindustrial enterprises and the ever-increasing demand for studies and research efforts aimed at promoting their economic sustainability, it is hoped that the approach proposed in this work can contribute to the development of analytical and planning processes in this area of activities.

Clearly, when compared with traditional project evaluation methods, the modelling effort required by the proposed approach is, to a large extent, more demanding in terms of time and expertise. Yet, it is believed that the learning process involved in model building and the potential insights derived from its use greatly compensate the additional effort. We also believe that the

system dynamics methodology provides an alternative to overcome some of the known shortcomings of the traditional methodology of project analysis.

Indeed, system dynamics allows the consideration of feedback loops and delays in the cause-effect relationships between key project variables, a feature that is not present in conventional project analysis methodologies. As opposed to the traditional sensitivity analysis approach followed in the financial evaluation of projects, which use essentially a comparative static method whereby the effects of a change in one single variable are reflected in a number of outcome indicators, a system dynamics model allows the simultaneous consideration of changes in several variables, be them qualitative or quantitative. Additionally, through feedback mechanisms these changes can lead to changes in the variables that generated them in the first place, unleashing in this way a number of adjustment processes. As illustrated by the scenario simulations presented in this paper, simultaneous changes reflect more realistically the systemic nature of interactions among variables that affect the outcome of a project. A modification in product prices, for instance, will not only affect the revenues of an enterprise, as the usual sensitivity analysis would imply. It will also affect product demand, which in turn affects firm production levels, leading to changes in inventories and costs, among other dynamic effects.

Moreover, contrasting to traditional sensitivity analysis, in a systems dynamics model the adjustments generated by changes in project variables are not necessarily instantaneously made: the methodology allows

for the consideration of delays between causes and effects.

For comprehensive agroindustrial development programs such as the one currently being initiated in Brazil⁴, the approach here discussed could be used to generate models of representative classes of agroindustrial enterprises (e.g. dairy plants, fruit and vegetable processing, manioc flour, grain mills, slaughterhouses, etc.). These, in turn, could help program managers to identify issues where close scrutiny in project analysis would be warranted, thereby reducing potential hurdles for the attainment of the economic sustainability goal.

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⁴ The Brazilian Ministry of Agrarian Development should invest about US\$ 700 million over a four year period, in order to create or upgrade 4400 small scale agroindustrial plants (PRONAF, 2003).

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