A systematic approach for the analysis of the economic viability of investment projects

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Abstract: This paper aims to present a systematic for the analysis of the economic viability of investment projects (SAEVIP) in fixed assets. In the literature, it is possible to identify the fundamental elements to evaluate the merit of the investment project (IP). To assess the dimension 'return', indicators are analysed: net present value (NPV), NPV annualised (NPVA), index benefit/cost (IBC), return on investment annualised (ROIA), index ROIA/minimum rate of attractiveness (MRA) and return on investment (ROI). An indicator analysis for dimension 'risk' is performed by internal rate of return (IRR), Payback, index MRA/IRR, index Payback/N and Fisher point. In addition, a joint assessment of indicator of risk and return is performed. A sensitivity study is promoted on the main variables involved in economic performance of the IP (MRA, costs and revenues). To validate the SAEVIP proposal, a case study shows the wealth of information generated by the application of this systematic.

Keywords: decision-making; IP; investment projects; fixed assets; economic analysis; sensitivity analysis; costs and revenues; discounted cash flow; multi-index methodology; returns and risks; verticalisation of production; planning and product development.

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1 Introduction

In economics, investment is the action of applying resources in means of production with expectation of future returns (Dixit and Pindyck, 1994). To ensure project approbation, it is necessary to consider technical issues. However, the technical approval of a project should be succeeded by a study of economic viability. This study indicates if its implementation is feasible (Buarque, 1989; Souza and Clemente, 2008; Luchtemberg et al., 2010; Rasoto et al., 2012).

It is not enough to develop an excellent project from the technical point of view, if it is unfeasible economically. Thus, a project is better evaluated if these two analyses have been developed. These analyses allow us to evaluate and simulate scenarios (optimistic, pessimistic and realistic) according to information collected in the market research (Rasoto et al., 2012; de Lima et al., 2013).

This paper presents a SAEVIP in fixed assets. Therefore, it is necessary to promote a joint assessment of indicators of risk and return, which consider depreciation, income tax (IT), social contribution on net profit (SCNP) and the financing source: own resources (ORs) or third-party resources (TPRs). With this assessment, the analysis is close to real.

By SAEVIP, the main contribution of this paper is to propose indicators to perform a sensitivity analysis on MRA, estimated costs and expected revenues. A real-world case study illustrates a SAEVIP application, addressing the verticalisation of production of cookers pressure-regulating valves for household use incorporating incremental improvements in product (Rozenfeld et al., 2006; Luchtemberg et al., 2010).

To achieve the proposed objective (SAEVIP), besides this introduction, this paper is organised into four sections. Section 2 presents the theoretical framework, which seeks to identify in the area of literature the main indicators to assess the economic viability adequately of an investment project. For this, the return and risk dimensions are observed, in addition to sensitivity analysis. The methodology is presented in Section 3. In this section, we describe the indicators identified in the literature as well as some indexes are proposed for the sensitivity analysis, which aims to improve the perception of risk. For ease of reading, mathematical demonstrations are placed in Appendix A.

Section 4 presents the results of the application of the SAEVIP in a real case based on the study of Luchtemberg et al. (2010). To facilitate understanding, relevant details of this study are set out in Appendix B. A more detailed description of the problem can be found in this reference. In this section, it is promoted a discussion on the interpretation, advantages and disadvantages of each indicator incorporated in the SAEVIP. Finally, Section 5 concludes the paper highlighting the main findings of research and pointing paths for future research on the economic evaluation subject.

2 Theoretical framework

According to Casarotto Filho and Kopittke (2010), when a company decides to install a new factory or expand a sector, an analysis of the economic viability should be done. To perform economic and financial analysis, the following criteria should be considered: economic (profitability of investment), financial (availability of resources) and imponderables (factors not convertible into money).

Casarotto Filho and Kopittke (2010) discussed that economic and financial analyses may not be sufficient for decision-making. For overall investment analysis, it may be necessary to consider non-quantitative factors such as qualitative nature constraints or the company macrogoals. There are two ways to assess whether a project is feasible from the economic point of view.

First, using non-exact (or not analytical) methods, which do not consider investment life and the value of money over time. The main non-exact method is time of return on invested capital or simple Payback time.

Before discussing the other evaluation method of the economic viability of IP, it is necessary to define the MRA. The MRA is the best rate of return, since it is associated with a low risk. In this context, for individual investors we can use the remuneration of savings account. For corporations, it is recommended the value of the return rate on public securities or defined by the company rate (Souza and Clemente, 2008; Casarotto Filho and Kopittke, 2010; Rasoto et al., 2012; de Lima et al., 2013).

Second, the other assessment approach uses the exact methods (or analytical methods), which, unlike the first one, consider the value of money over time. Within this evaluation methodology, some authors use only the NPV, IRR and Payback (Buarque, 1989; Bruni et al., 1998; Casarotto Filho and Kopittke, 2010).

On the other hand, other authors prefer rating as the exact method by using a multi-index methodology. This is based on the decision-making process regarding the acceptance or rejection of certain IP using various indicators, usually separated into groups of return and risk. Among the indicators of return are: present value (PV), NPV, net present value annualised (NPVA), IBC or liquidity index (LI), ROIA, index ROIA/MRA and ROI. The indicators of risk are IRR, index MRA/IRR (risk of applying MRA earns more than the IP), Payback, corrected Payback, index Payback/N (risk that the project does not pay) and Fisher point (Fisher, 1961; Buarque, 1989; Souza and Clemente, 2008; Casarotto Filho and Kopittke, 2008; Rasoto et al., 2012; de Lima et al., 2013).

2.1 Techniques of sensitivity analysis for IP

The cash flow is built on the basic structure of costs and revenues linked to the project under study. In traditional analysis presented so far, we considered the expected costs, the estimated revenue and the proposing company MRA of the investment project as constants. In general, these parameters are established based on a certain level of basic production, defined by market steps, project size and engineering (Buarque, 1989; Bruni et al., 1998). According to these authors, the values assigned to these parameters undergo changes owing to forecasting errors. The change in revenues may be due to variation in production, demand or prices. On the other hand, the operational or maintenance costs may have been underestimated or overestimated. This situation is magnified for innovation projects in which there is no history and, therefore, there is a greater likelihood that the projected values are farther from those done.

In Section 3, indicators to assess the sensitivity of the main variables involved in the decision-making process (MRA, costs and revenues) are proposed. The strategy adopted in the identification of new indicators was changing a parameter, keeping the remaining constant and finding the break-even point between the estimated costs and expected revenues. Appendix A presents a demonstration of mathematics for each proposed indicator.

3 Methodological procedures

3.1 Model

The SAEVIP was established based on index for return and risk existing in the literature. The SAEVIP consists of indicators in three dimensions, which are return, risk and a sensitivity analysis that aims to improve the perception of risk associated with the IP in this study. The latter is complemented by verification of the spectrum of the decision validity. Figure 1 shows the dimensions considered with their respective indicators and parameters of inputs.

The information necessary for implementing the SAEVIP is shown in the last column of Figure 1. The starting point of the SAEVIP is to collect data that will provide the following information:

- MRA
- planning or analysis horizon (N)
- the initial investment or cash flow zero (CF_0): cost of acquisition, transportation, installation and initial funding of working capital, for example
- residual value or resale (RV): expected value at the end of the project
- total estimated cost per period j (Cj)
- revenue expected per period j (Rj)
- cash flow per period j (CFj), this is: $CFj = Rj - Cj$
- depreciation approach: linear or exponential, for example

- financing source: fund agencies (Brazilian Development Bank – BNDES, for example), amortisation system (CAS or PRICE or mixed), interest rate, maximum term, percentage financeable and existence of grace period
- aliquot of income tax (IT) and SCNP.

Figure 1 SAEVIP (see online version for colours)

Dimension	*Indicator and formula*	*Input*
Return	$PV = \sum_{j=1}^{N} \frac{CF_j}{(1+MRA)^j}$	MRA, N, CF_0, CF_j and N
	$NPV = -\lvert CF_0 \rvert + PV$	PV and CF_0
	$NPVA = \frac{NPV \times [MRA \times (1+MRA)^N]}{[(1+MRA)^N - 1]}$	NPV, MRA and N
	$IBC = \frac{PV}{\lvert CF_0 \rvert}$ or $IBC = \frac{VP(R)}{VP(C)}$	PV and CF_0 or VP(R) and VP(C)
	$ROIA = \sqrt[N]{IBC} - 1$	IBC and N
	$Index\ ROIA/MRA = \frac{ROIA}{MRA}$	MRA and ROIA
	$ROI = (1+MRA) \times (1+ROIA) - 1$	MRA and ROIA
Risk	$-\lvert CF_0 \rvert + \sum_{j=1}^{N} \frac{CF_j}{(1+IRR)^j} = 0$	N, CF_0 and CF_j
	Payback – Minimum {j} such that: $\sum_{j=1}^{N} \frac{CF_j}{(1+MRA)^j} \geq \lvert CF_0 \rvert$	N, MRA, CF_0 and CF_j
	$Index\ MRA/IRR = \frac{MRA}{IRR}$	MRA and IRR
	$Index\ Payback/N = \frac{Payback}{N}$	Payback and N
Sensitivity analysis	$\Delta\%MRA_{max\uparrow} = \frac{IRR}{MRA} - 1$	IRR and MRA
	$\Delta\%C_{max\uparrow} = IBC - 1$	IBC
	$\Delta\%R_{max\downarrow} = 1 - \frac{1}{IBC}$	IBC
	$\Delta\%(C_{max\uparrow} \cap R_{max\downarrow}) = \frac{IBC - 1}{IBC + 1}$	IBC
Spectrum of decision validity	Fisher point = IRR of CF resulting from the difference between two projects	IRR
	Graphic: NPVs x MRAs	MRAs, N, CF_0 and CF_j

Such information allows calculating the indicators of risk and return associated with IP on study. The indicators relating to return expected incorporated are PV, NPV, NPVA, IBC, ROIA, index ROIA/MRA and ROI. On the other hand, to assess the perception of the associated risk with the IP on study, it is necessary to use: IRR, Payback discounted or corrected (this latter for projects financed with use of grace – de Lima et al., 2013), index MRA/IRR, index Payback/N and Fisher point (comparison of two or more projects). In addition, to check until this decision is valid, it is important analysing the relationship between the NPVs and the discount rates, by two-dimensional Cartesian graph.

The case study shows interpretation and limitation of risk and return indicators. Furthermore, it promotes a sensitivity analysis on costs, revenues and MRA, which is the main contribution of this paper. In this way, the following indicators are proposed:

- $\Delta\%MRA_{máx}\uparrow$ = IRR/MRA – 1, to determine the (increase) maximum percentage variation on the MRA before making the project economically unviable
- $\Delta\%C_{máx}\uparrow$ = IBC – 1: to determine the (increase) maximum percentage variation on costs that maintains the project economically viable
- $\Delta\%R_{máx}\downarrow$ = 1 – 1/IBC: to determine the (reduction) maximum percentage change permitted on revenue before making the project economically unviable
- $\Delta\%(C_{máx}\uparrow \cap R_{máx}\downarrow)$ = (IBC – 1)/(IBC + 1): to determine the maximum percentage variation permitted concurrently on costs (increase) and revenues (reduction) before making the project economically unfeasible.

To obtain these results, we used the break-even point between the MRA and the IRR to determine the maximum variation in MRA, maintaining the project viability. In the same way, break-even points between the benefits and costs were used to determine the maximum variations in revenues and costs. The mathematical proofs can be found in Appendix A.

3.2 Case study

The SAEVIP is illustrated by an actual case based on the study of production verticalisation of pressure-regulating valves developed by Luchtemberg et al. (2010). To facilitate understanding, the cost estimates (initial investment, operation and maintenance costs) and revenues associated with the IP of this study are set out in Appendix B. The more detailed description of the problem of verticalisation can be found in this reference.

A computer application was developed in the MS-Excel® calculation spreadsheet to partially automate the SAEVIP. Thus, as the technical procedures, this research is characterised as a case study (Martins et al., 2014). Section 4 presents the results found with the application of SAEVIP to that case.

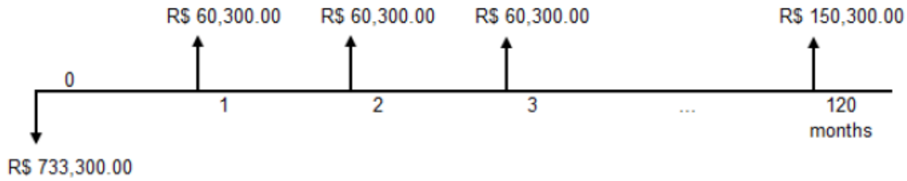
4 Results and discussion

In this section, a real-world case study illustrates the SAEVIP proposal. For this purpose, the SAEVIP application shows how to implement opportunities for improvement identified in Luchtemberg et al. (2010), bringing results to a real context to incorporate on analysis of the effects of linear depreciation, the IT, the SCNP and source of funding (OR or TPR). In addition, it presents the results obtained for the proposed indicators of sensitivities.

The economic analysis starts on information collection (demand, revenues and costs) for the production verticalisation of pressure-regulating valves focused on incremental improvement of the product (Luchtemberg et al., 2010). Currently, the organisation in question has an average production of 300,000 units per month. The study was developed for this amount up to 400,000 units. Details of estimated costs, expected revenues and projections of cash flows are found in Appendix B.

To perform the production verticalisation, an initial investment of R$ 733,000.00 is required. It is expected that the production manages itself a cash surplus in the order of R$ 60,300.00, representing the difference between revenues and costs for maintenance and operation of the IP in study. The last element of the cash flow (CF) is differentiated by incorporating the residual value (RV), totalling R$ 150,300.00. It is emphasised that it was not considered the inflation impact on the CF, which would be equivalent to consider it as a homogeneous rate (Casarotto Filho and Kopittke, 2010; de Souza and Kliemann Neto, 2012). These results are highlighted in the diagram of the CF exposed in Figure 2.

Figure 2 Cash flow diagram of IP in study



The MRA represents the minimum that an investor proposes to receive back. In this sense, it is used as MRA the monthly value of 0.8%, corresponding to the SELIC rate (Special Liquidation and Custody System of Brazil). The planning or analysis horizon is of 10 years (120 months). Table 1 shows the table input for the SAEVIP proposal. Table 2 presents the results found for the case study in the evaluated scenarios: OR or TPR. The calculations were performed by using spreadsheet calculations on MS-Excel®.

Observation of the data exposed in Figure 2 allows concluding that the process of verticalisation is economically viable independent of the funding source: OR or TPR. It is noteworthy that some advantages were not measured economically, such as:

- do not depend on third parties
- reduction of logistics problems
- be able to make the statistical control of the process.

However, it is necessary to analyse the results found for each indicator weighing up risks and returns of each project under study.

The expectation is the organisation recovers the investments made for the verticalised production of pressure-regulating valves, considering a monthly MRA of 0.8% generating monetary values of R$ 3,311,253.71 (OR) or R$ 3,342,548.36 (TPR). The information of the NPV is not enough to support an investment decision. It shows an overall result and not an outcome per period.

The information of the NPVA means that, depending on the future scenarios for economy, the monthly gains resulting from the production verticalisation is R$ 43,028.32 (OR) or R$ 43,434.98 (TPR) in addition to those obtained by the application of resources to MRA.

The IBC corrects partially the NPV and NPVA deficiency that is to express the return in absolute values. The IBC is a relative indicator and measures the expectation of return for each unit of capital assets in the project for the entire planning horizon. For the production verticalised pressure, the expectation is to obtain for each immobilised monetary unit 5.52 (OR) or 5.56 (TPR).

Table 1 Input of SAEVIP

Input	MRA	0.80% the month or 10.03% the year
	N	120 months or 10 years
	Rate (IT+SCNP)	15%
	Financing (rate)	0.70% per year or 8.73% per month
	Financing (term)	60 months
	Amortisation system	CAS (constant no grace period)
	% fundable	80%
	Linear depreciation	6,108.33 R$/month
	CF_0 (initial Cash Flow)	R$ 733,000.00
	RV (Residual Value)	R$ 90,000.00
	$C_j, j = 0, 1, ..., n$	Different values for each period (j)
	$R_j, j = 0, 1, ..., n$	Different values for each period (j)
	$CF_j, j = 0, 1, ..., n$	$CF_j = R_j – C_j$

Table 2 Frame SAEVIP and results

Category/dimension	*Indicator*	*Own resources*	*Financing CAS + MRA*
Return	PV	R$ 4,044,253.71	R$ 4,075,548.36
	NPV	R$ 3,311,253.71	R$ 3,342,548.36
	NPVA (monthly)	R$ 43,028.32	R$ 43,434.98
	IBC or LI	5.5174	5.5601
	ROIA (monthly)	1.43%	1.44%
	Index ROIA/MRA	179.18%	179.99%
	ROI	2.24%	2.25%
RISC	IRR	7.12%	6.49%
	Payback	15	17
	Index MRA/IRR	11.24%	12.32%
	Index Payback/N	12.50%	14.17%
Sensitivity analysis	$\Delta\%MRA_{máx}\uparrow$	789.48%	711.72%
	$\Delta\%C_{máx}\uparrow$	451.74%	456.01%
	$\Delta\%R_{máx}\downarrow$	81.88%	82.01%
	$\Delta\%(C_{máx}\uparrow \cap R_{máx}\downarrow)$	69.31%	69.51%
	Greater sensitivity	Revenue	Revenue
Spectrum of decision validity	Fisher point	0.59%	
	Graphic: NPVs × MRAs	See Figure 3	

According to a concept from economics area (economic value added (EVA)), the SAEVIP uses ROIA indicator to assess the profitability of the IP in study instead of IRR. The ROIA is the best estimate of profitability of an IP. It represents, in percentage terms, the wealth generated by the project. The project under analysis presents monthly an

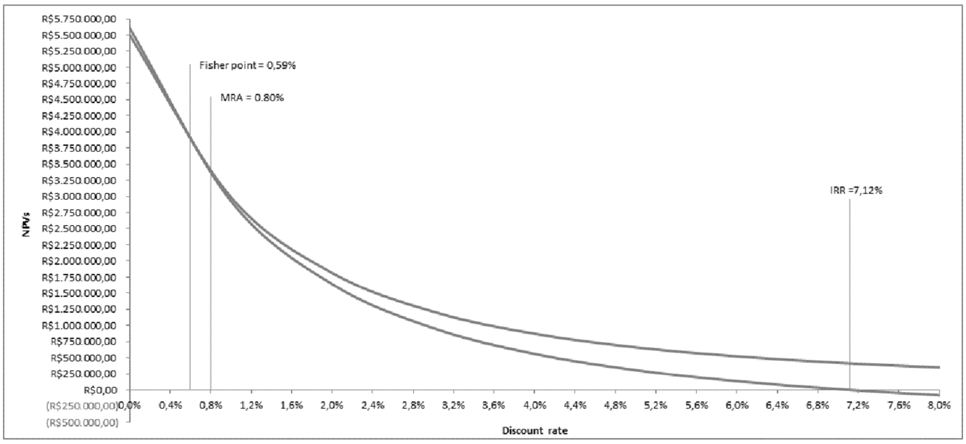
ROIA of 1.43% (OR) or 1.44% (TPR) beyond the MRA. This information is the best estimate of profitability of the IP as the production verticalisation. The decision at this point is to discuss if it is worth investing on project (assuming the investment risk) to have the estimated additional gain.

The IRR is the rate that makes the NPV null (and also the NPVA) of a CF, by setting a limit to the variation of the MRA. While the MRA (0.80% per month) remains less than the IRR (7.12% per month for OR or 6.49% for TPR), there is more gain in investing in the project than to apply it to MRA. Thus, the proximity (distance) between the IRR and the MRA may represent the risk (or security) of the project. Here, the risk is being interpreted as the possibility of having a better gain in verticalisation project than to leave the value applied to MRA.

For the financial market, remunerating the same level of IP is necessary that the MRA increases to 789.48% (OR) or 711.72% (TPR). These percentages show the safety of projects.

Figure 3 illustrates this situation, showing the behaviour of the NPV in function of variation in the MRA. It is emphasised that the objective is to analyse the spectrum of the decision validity taken on the basis of the return and risk indicators.

Figure 3 Relationship NPVs vs. discount rate



The Payback represents the time required for the recovery of investment. It can be interpreted as a measure of risk. With the increase in the time period for returning the invested capital, the risk rises. The result shows a very low risk, because the time of return is estimated at 15 months (8.33% for OR) or 17 months (9.44% for TPR) in an analysis horizon of 120 months.

The proposed indicators of sensitivity reveal that the costs of production may grow up to 451.74% (OR) or 456.01% (TPR) before making the project economically unfeasible. There is a greater sensitivity in revenues, being that the economic unviability occurs for reductions greater than 81.88% (OR) or 82.01% (TPR).

The indicators of return are best for the financing, however, the risk measured by Payback/N and MRA/IRR indexes are larger. In addition, with an MRA of 0.8% and a point of Fisher of 0.59%, the decision by financing is maintained even with change (increase) of the MRA.

It is noteworthy that the organisation must be concerned with the degree of participation of third-party capital on the capital structure of the company. Considering the exposed above, it is recommended the implementation of IP through the funded modality. In this case, the surplus capital can be applied to MRA until a new investment opportunity.

5 Conclusion

This paper presented two main contributions to the theme:

- the proposition of indicators to analyse the sensitivity of the MRA, costs and revenues
- development of a SAEVIP based on literature review and incorporation of proposed sensitivity indicators.

The application of the SAEVIP demonstrated that production verticalisation of cookers pressure-regulating valves is appropriated under the economic issues. The sensitivity analysis allowed checking the performance impacts of the project by means of changes in key variables. On the basis of the results, it is recommended to produce the valves instead of buying ones, using external capital as a financial source.

In general, to perform the sensitivity analysis, it is necessary to achieve the goal of identifying the system variables impact in the economic indicators. However, it is emphasised that the sensitivity analysis is also a measurement method of deterministic risk. In this sense, it is recommended the development of new techniques for sensitivity analysis or the improvement of the approach presented in this paper, for example, to evaluate the effect on Payback owing to changes in the MRA. Other suggestions include:

- to apply a technique of scenarios analysis, in which it is evaluated the impact of various parameters in a concomitant way (Gitman and Zutter, 2014)
- to perform a conventional statistical/mathematical treatment for non-deterministic factors (Souza and Clemente, 2008)
- to apply a simulation method, such as Monte Carlo method (Bruni et al., 1998).

In addition, it is recommended to develop an approach, which advances beyond conventional analyses of costs, revenues and discounted cash flows, for example, including strategic issues of the IP proposer company.

For further research, we suggest using the real options theory (Brealey et al., 2011), the investment theory under uncertainty (Hertz, 1964; Dixit and Pindyck, 1994) and the incorporation of a heterogeneous inflation (de Souza and Kliemann Neto, 2012) to complement the SAEVIP. Another approach consists in the cost-volume-profit analysis to determine the quantity produced in the break-even point and check the used percentage of revenue (Rasoto et al., 2012).

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References

Brealey, R., Myers, S.C. and Allen, F. (2011) *Principles of Corporate Finance*, 10th ed., McGraw-Hill, New York.

Bruni, A.L., Famá, R. and Siqueira, J.O. (1998) 'Análise do risco na avaliação de projetos de investimento: uma aplicação do Método de Monte Carlo', *Cadernos de Pesquisa em Administração*, Vol. 1, No. 6. pp.62–74.

Buarque, C. (1989) *Avaliação Econômica de Projetos*, 4th ed., Campus, Rio de Janeiro.

Casarotto Filho, N.C. and Kopittke, B.H. (2010) *Análise de Investimentos: Matemática Financeira, Engenharia Econômica, Tomada de Decisão, Estratégia Empresarial*, 11th ed., Editora Atlas S.A, São Paulo.

de Lima, J.D., Scheitt, L.C., de Boschi, T.F., da Silva, N.J., de Meira, A.A. and Dias, G.H. (2013) *Propostas de Ajuste no Cálculo do Payback de Projetos de Investimentos Financiados*, Custos e@gronegócio online, Vol. 9, No. 4, pp.162-180, Available via www. custoseagronegocioonline.com.br. Cited 12 March 2014.

de Souza, J.S. and Kliemann Neto, F.J. (2012) 'O impacto da incorporação da inflação na análise de projetos de investimentos', *Produção*, Vol. 22, No. 4, pp.709–717.

Dixit, A.K. and Pindyck, R.S. (1994) *Investment under Uncertainty*, Princeton University Press, Princeton.

Fisher, I. (1961) *The Theory of Interest*, Reprints of Economic Classics, The Macmillan Co., New York.

Gitman, L.J. and Zutter, C.J. (2014) *Principles of Managerial Finance*, 14th ed., Prentice Hall: Pearson Series in Finance, New York.

Hertz, D.B. (1964) 'Risk analysis in capital investment', *Harvard Business Review*, pp.95–106.

Luchtemberg, I.C., de Lima, J.D., Trentin, M.G. and Oliveira, G.A. (2010) *Viabilidade Técnica e Econômica da Verticalização na Produção de Válvula Reguladora de Pressão para Panelas de Pressão em Indústria de Artefatos de Alumínio*, XXX Encontro Nacional de Engenharia de Produção. São Carlos/SP – Brasil.

Martins, R.A., Mello, C.H.P. and Turrioni, J.B. (2014) *Guia de Elaboração de Monografia e TCC em Engenharia de Produção*, 1st ed., Atlas, São Paulo.

Rasoto, A., Gnoatto, A.A., Oliveira, A.G. de, Rosa, C.F. da Ishikawa, G., Carvalho, H.A., de Lima, I.A. de Lima, J.D., de Trentin, M.G. and Rasoto, V.I. (2012) *Gestão Financeira: Enfoque em Inovação*, Aymara, Vol. 06, Série UTFinova, Curitiba.

Rozenfeld, H., Forcellini, F.A., Amaral, D.C., Toledo, J.C., Silva, S.L., Alliprandini, D.H. and Scalice, R.K. (2006) *Gestão de Desenvolvimento de Produtos: Uma Referência Para a Melhoria do Processo*, Saraiva, São Paulo.

Souza, A. and Clemente, A. (2008) *Decisões Financeiras e Análise de Investimentos: Fundamentos, Técnicas e Aplicações*, 6th ed., Atlas, São Paulo.

Appendix A: Mathematical demonstrations

The goal of the proposed approach is to identify the break-even point (BEP) for each particular situation. If, after consideration of risk and return, the IP is feasible in the preliminary analysis, then the BEPs found represent the maximum variation (elevation of MRA, increased costs and reduced revenue) admitted before to make the IP unfeasible. On the other hand, if the IP is unfeasible, the BEPs represent the minimum variation (reduction in the MRA, reduction of costs and increased revenues) needed to make the project feasible.

In the analysis of risk and return it was considered that MRA, estimated costs and expected revenues remain constant during the execution of the project. However, this prediction may not be confirmed. To overcome this limitation, we seek to promote changes in one of the parameters (MRA, costs or revenues) and check the impact of this variation on the economic viability of the project under study. For this purpose, it is called:

$$B = \sum_{j=1}^{N} \frac{B_j}{(1+MRA)^j}; \quad C = \sum_{j=0}^{N} \frac{|C_j|}{(1+MRA)^j}$$

and

$$\text{IBC} = \frac{\sum_{j=1}^{N} \frac{B_j}{(1+MRA)^j}}{\sum_{j=0}^{N} \frac{|C_j|}{(1+MRA)^j}} = \frac{B}{C}$$

To facilitate the understanding it is adopted an approach in the form of questions. They are:

- Until how much may the MRA vary if the IP under study must remain viable and the other parameters (costs and revenues, for example) are maintained constant?

With this purpose, the sensitivity analysis is performed on MRA. Knowing that the project is still viable while the in equation is true: MRA ≤ IRR and considering λ as being the maximum percentage variation permitted of MRA, the BEP is determined through:

$$\text{MRA} \cdot (1+\lambda) \overset{*}{=} \text{IRR} \Rightarrow 1+\lambda = \frac{\text{IRR}}{\text{MRA}} \Rightarrow \lambda = \frac{\text{IRR}}{\text{MRA}} - 1$$

*break even-point (BEP).

It should be noted that this analysis assumes that IRR ≥ MRA and that costs and revenues remain constant during the planning or analysis horizon.

- What is the maximum percentage variation permitted in costs that still maintain the economic viability of the project under study?

In this sense, we seek the sensitivity analysis on costs. The reasoning is analogous to the first question. However, in this analysis it was used as a presupposition that IBC ≥ 1 and that MRA and the revenues remain constant during the planning or analysis horizon.

$$\frac{B}{C \cdot (1+\lambda)} \overset{*}{=} 1 \Rightarrow \frac{B}{C} = 1+\lambda \Rightarrow \lambda = \frac{B}{C} - 1 = \text{IBC} - 1$$

*break even-point (BEP).

- What is the maximum percentage variation permitted in revenues that still keep the economic viability of the project under study?

For this purpose, there is a sensitivity analysis on the revenues. In a similar way to the second question, it was used as a basis for this analysis that IBC ≥ 1 and that MRA and costs remain constant during the planning or analysis horizon.

$$\frac{B\cdot(1-\lambda)}{C}\overset{*}{=}1 \Rightarrow 1-\lambda=\frac{C}{B}\Rightarrow \lambda = 1-\frac{C_{\div C}}{B_{\div C}}=1-\frac{1}{\text{IBC}}$$

*break even-point (BEP).

- What is the maximum percentage variation permitted simultaneously for revenues and costs in order to maintain the economic viability of IP? For both, we applied a sensitivity analysis on costs and revenues.

In an analogous manner, it was used as a basis of analysis that IBC ≥ 1 and that TMA remains constant during the planning horizon.

$$\frac{B\cdot(1-\lambda)}{C\cdot(1+\lambda)}\overset{*}{=}1 \Rightarrow B-B\cdot\lambda = C+C\cdot\lambda \Rightarrow$$

$$B-C=B\cdot\lambda+C\cdot\lambda \Rightarrow B-C=\lambda\cdot(B+C)\Rightarrow$$

$$\lambda=\frac{B-C}{B+C}\overset{\div C}{=}\frac{\frac{B}{C}-1}{\frac{B}{C}+1}=\frac{\text{IBC}-1}{\text{IBC}+1}$$

*break even-point (BEP).

Appendix B: Costs, revenues and initial investment

Source: Adapted from Luchtemberg et al. (2010)

The results described here were researched in sector companies and within the organisation itself. A survey of information was carried out related to:

- cost of materials
- amount of money spent on research
- values with the personal development of machines and equipment
- cost of consumable materials
- personnel costs for operations
- research of the useful life of machines and equipment, for example.

Project investments (CF_0)

Currently, the organisation in question has an average monthly production of 300,000 units. In the development of the economic-financial study it was considered a maximum production of 400,000 units per month. A production above this level will require a reassessment of the project of economic viability, since there will be a need for new initial investments and also changes in the cash flows. Table 3 shows the values for the initial investment of the verticalisation project of pressure regulating valves production.

Table 3 Initial investment in research, projects, machines, tools and implementation

Item	*Description*	*Value*
1	Research and Development (R&D)	R$ 25,000.00
2	Project execution	R$ 35,000.00
3	Die casting machine (cold chamber)	R$ 450,000.00
4	Die casting die with 16 cavities	R$ 110,000.00
5	Eccentric press (25 tons)	R$ 25,000.00
6	Stamping tool (washer)	R$ 18,000.00
7	Tapping machine (washer)	R$ 25,000.00
8	Assembly machine	R$ 45,000.00
Total		*R$ 733,000.00*

Production costs (C_j)

In this step, the costs of raw materials and labour to assemble the pressure regulating valve are presented. The values described refer to those practiced by the organisation in its current process. These values were applied in this project to study the feasibility of the production verticalisation of said pressure regulating valve. The main costs are shown in Tables 4 and 5.

Table 4 Cost of raw material (RM)

Item	*Description*	*Unit*	*Quantity*	*Value*	*Unit cost*
1	Valve	kg	0.029	R$ 5.50	R$ 0.16
2	Plastic cover	un	1	R$ 0.06	R$ 0.06
3	Washer	un	0.003	R$ 5.50	R$ 0.02

Table 5 Cost of direct labour (CDL)

Item	*Description*	*Unit*	*Quantity*	
1	Casting of the valve	h	220	…
2	Washer manufacturing (labour)	h	220	…
3	Assembly	h	220	…
Item	*Description*	*Value*	*Total value*	*Unit cost*
1	Casting of the valve	R$ 9.00	R$ 1,980.00	R$ 0.007
2	Washer manufacturing (labour)	R$ 4.23	R$ 931.00	R$ 0.003
3	Assembly	R$ 4.23	R$ 931.00	R$ 0.003

The values found in Table 6 were based on the historical processes practiced by the organisation in question. On the other hand, the costs of maintenance and operation of machines and equipment were provided by the respective manufacturers and analysed by teams of industrial maintenance and process of the organisation.

Table 6 Consumption and maintenance

Item	*Description*	*Unit*	*Quantity*	
1	Alcohol	L	200	…
2	Tap 3/8”	un	20	…
3	Electric power	kWh	20,120	…
4	Maintenance	–	–	…
Item	*Description*	*Value*	*Total value*	*Unit cost*
1	Alcohol	R$ 1.35	R$ 270.00	R$ 0.001
2	Tap 3/8”	R$ 38.00	R$ 760.00	R$ 0.003
3	Electric power	R$ 0.12	R$ 2,534.00	R$ 0.008
4	Maintenance	–	R$ 1,000.00	R$ 0.003

By adding the values in Tables 4–6 it follows that the total unit value to produce internally the regulating valve is of R$ 0.268.

Comparative costs

The comparison of values between buying the pressure regulating valves or producing them internally by verticalising the production (make-or-buy), was started by a simple confrontation between these two values. Currently the value practiced on the market by suppliers of this product is of R$ 0.469, which is compared with the total estimated cost of domestic production (R$ 0.268). The difference between these values, which is of R$ 0.201, is used as the basis of the economic viability study of the production verticalisation by the organisation, as outlined in Section 4.