Productivity depending risk minimization of production activities

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Abstract: - Production activities depend on a number of important parameters, one being the personnel's productivity. This parameter affects considerably the risk (technical and/or financial risk) of the whole activity. For the computation of the risk, a simple but comprehensive computer model has been created allowing the time simulation of the production process for a number of possible expected returns (scenarios), as well as the computation of the (well known) financial indices *ROI*, *IRR* and *NPV*. For the risk minimization the 'min-max strategy' for determining optimal strategies has been applied. The "min-max strategy" guarantees a worst-case risk/return tradeoff in terms of the above financial indices, whichever of the specified scenarios occurs. The above method is described in the following and corresponding results are presented in this paper.

Key words: - Risk modeling, Risk minimization, Min-max strategy**,** Productivity

1 Introduction

For the planning of production activities (i.e. investment activities, industrial production activities, etc.) computer models for computing the technical and/or financial risk as well as risk-minimum strategies, are in use since a long time. For the computation of risk-minimum strategies numerous methods exist, like the mean variance approach, stochastic multi-period optimization, continuous time methods, factor models, etc. [1]-[10].

Newly, Rustem, Becker and Marty [2] introduced the 'min-max strategy'. The proposed method considers a finite set of possible expected returns, called 'scenarios', and uses a strategy that guarantees a worst-case risk/return tradeoff, whichever of the specified scenarios occurs.

In this paper we apply the 'min-max strategy' for computing the impact of personnel's productivity on the financial risk indices *ROI*, *IRR* and *NPV*. This is important for exploring the sensitivity of the financial risk from the qualification of the working personnel and from the management's performance.

In this investigation we consider the model already developed in [12], but with some modifications that are described in section 2. The same holds for the optimization method necessary for determining the optimal strategy, which is already introduced in [11]. Finally, the results of the study are presented and commented in sections 5 and 6.

2 Model Description

We consider (see [12]) the case of a production activity for a time period of *T* years, subdivided in yearly quarters "*q*" (q=1,…,Q).

The total investment for the production activity is equal to I_{Total}. The investment *Inv* is assumed to be realized within N ($N<Q$) yearly quarters and to vary linearly with q:

$$Inv(q) = (2 \cdot I_{Total} / N) \cdot (1 - q / N),\ q = 1,..,N \quad (1)$$

The maintenance costs *MainC* for the production equipment (e.g. machines, etc.) in each yearly quarter q are equal to

$$MainC(q) = \alpha \cdot I_T, \quad q = N+1,...... \quad (2)$$

with α denoting a fixed percentage of I_{Total}.

The expenses for the business operation include the personnel costs *PersC*, the operating costs

OperC and the marketing costs *MarkC*. The personnel costs *PersC* depend on the number of employees *Empl*, their initial salary *SalC*, and the salary raise *SalR*. Therefore:

$$PersC(q) = Empl(q) * SalC(q) \qquad (3)$$
$$SalC(q) = SalC(q-1) * (1 + SalR)$$

The operating costs *OperC* consist of an inelastic part defined by the constant β_1 (e.g. rent, cleaning, security, etc.) and of a variable part (e.g. telephone, consumables, travelling, etc) which depends on the constant β_2 and the number of employees *Empl*.

$$OperC(q) = \beta_1 + \beta_2 \cdot Empl(q) \qquad (4)$$

For the current production activity, the assumption is made that the marketing costs *MarkC* are high at the beginning of the business (in order to stir the market) and are decreasing during the *T* years period, controlled by the constants γ_1 and γ_2:

$$MarkC(q) = \gamma_1 \cdot (1 + 10^{-\gamma_2 \cdot q}) \qquad (5)$$

With respect to the incomings *Inc*, we assume that each employee produces a constant incoming Inc_E according to his productivity *P*. Then the total incoming is given by the equation (6).

$$Inc(q) = Inc_E \cdot P \cdot Empl(q) \qquad (6)$$

The productivity *P* depends on two factors: At the beginning of the activity, the productivity is expected to follow the well known "learning curve" *L*, which is assumed to be of exponential type and is defined by two constants λ_1 and λ_2:

$$L(q) = \lambda_1 + (1 - 10^{-\lambda_2 \cdot q}) \cdot (1 - \lambda_1) \qquad (7)$$

The productivity *P* is also expected to drop with the increase of the number of the employees, since management and coordination problems encounter if the number of employees is big. The productivity loss P_L is assumed to be linear and to is described given by the following equation:

$$P_L(q) = P_{L30} + \frac{P_{L150} - P_{L30}}{120}[Empl(q) - 30] \qquad (8)$$

In equation (8) P_{L30} is the estimated productivity loss for 30 employees and P_{L150} the estimated productivity loss for 150 employees. Therefore:

$$P = L(q) - P_L(q) \qquad (9)$$

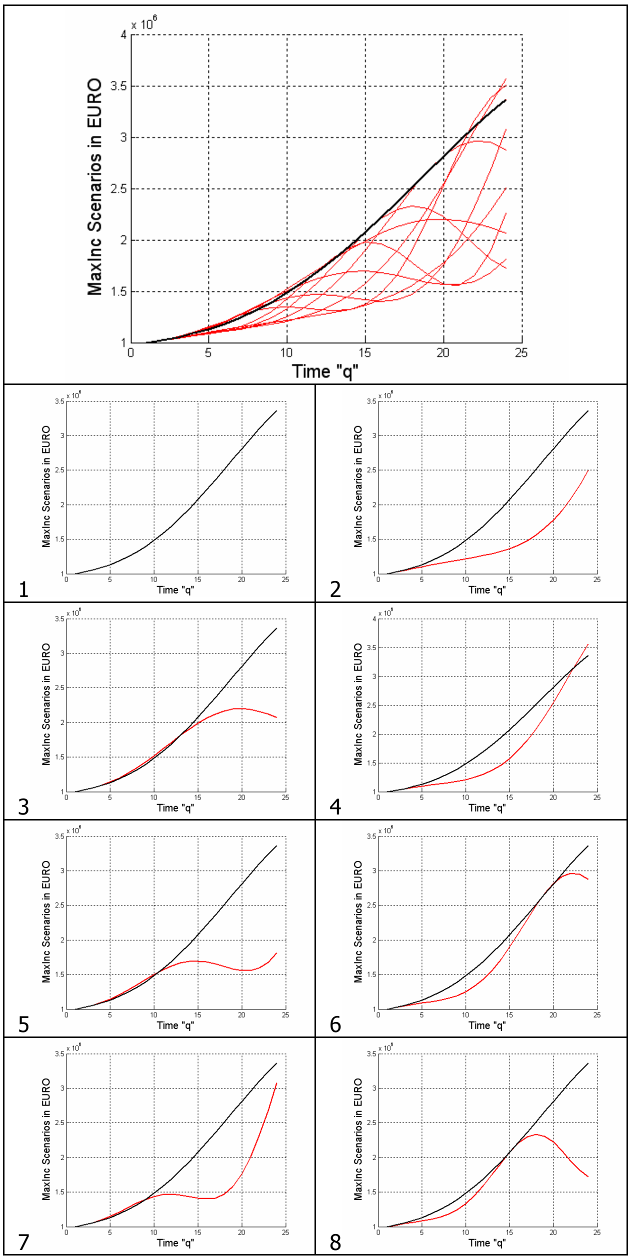
3 Scenarios

We consider a finite set of possible (including the worst case) expected returns or incomings $MaxInc(s)$, s=1,…,S, called scenarios. For these scenarios the following constraint holds:

$$Inc \le MaxInc(s) \qquad (10)$$

This means that the incomings defined through eq. (6) have $MaxInc(s)$ as upper bound.

For the case under consideration, 10 *MaxInc* scenarios are defined and are shown in Figure 1. Scenario 1 is considered to be the 'basic' scenario.



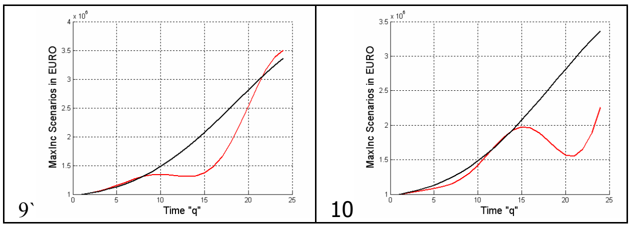


Figure 1. The ten individual s=1-10 scenarios *MaxInc* (in €) and all in concert.

For a given distribution of the number of employees over the total time period T: $Empl(q)$ (q=1,…,Q), the following financial risk indices

- *NPV* (Net Present Value),
- *IRR* (Internal Rate of Return) and
- *ROI* (Return of investment)

can be computed. It is clear that these financial risk indices mirror through the modeling of eq. (1)-(9) also the organizational and productivity aspects.

4 Risk Minimization

In the present case the risk minimization problem consists in maximizing the minimum $NPV(s)$ according to equation (11):

$$\min[NPV(s),\ \ s = 1,..,S] = \max \tag{11}$$

The above min-max problem has Q independent variables, namely $u(q)=Empl(q)$, q=1,…,Q.

For the solution of this problem a novel hybrid evolutionary strategy is proposed [11]. It consists of the Evolution Strategy (ES) with one parent and one offspring combined with the deterministic Nelder-Mead algorithm.

According to this method, for each vector $\mathbf{a}_{ev}$ (created by the ES)

$$\mathbf{a}_{ev} = [u(1),\ u(2),\ \ldots, u(Q)] \tag{12}$$

the Nelder-Mead algorithm takes over and yields the nearest local minimum $\mathbf{a}_{min}$. Then, if two successive random vectors lead to the same local minimum, the standard deviation σ (and thus the search area) is increased.

The proposed hybrid optimization method reads:

- set initial vector $\mathbf{a}_0$
- ❖ m =1 (cycle)
- set σ_0

for n=1:N create random vectors

$${}^{n}\mathbf{a}_{ev}\,(\mathbf{a}_0,\ \sigma_0);$$

find the nearest local minimum ${}^{n}\mathbf{a}_{min}$; (13)

if $J[{}^{n}\mathbf{a}_{\min}] - J[{}^{n-1}\mathbf{a}_{\min}] \le \zeta \cdot J[{}^{n-1}\mathbf{a}_{\min}]$

then $\sigma_{n+1} = \xi \cdot \sigma_n$

➔ $\mathbf{a}_{opt}$ is the ${}^{n}\mathbf{a}_{\min}$ for which $J[{}^{n}\mathbf{a}_{\min}]$=smallest

❖ increase m=m+1

Typical ζ and ξ values are ζ=0.05 and ξ=1.15. For further information see [11].

5 A First Optimization Result

If P=1 and the basic scenario s=1 is considered, then the optimal strategy $u_{s=1}$ can be easily computed (see Figure 2a): The $NPV(s{=}1)$ value results in

$$NPV_{s=1}=1.8303e{+}006\ € \tag{14}$$

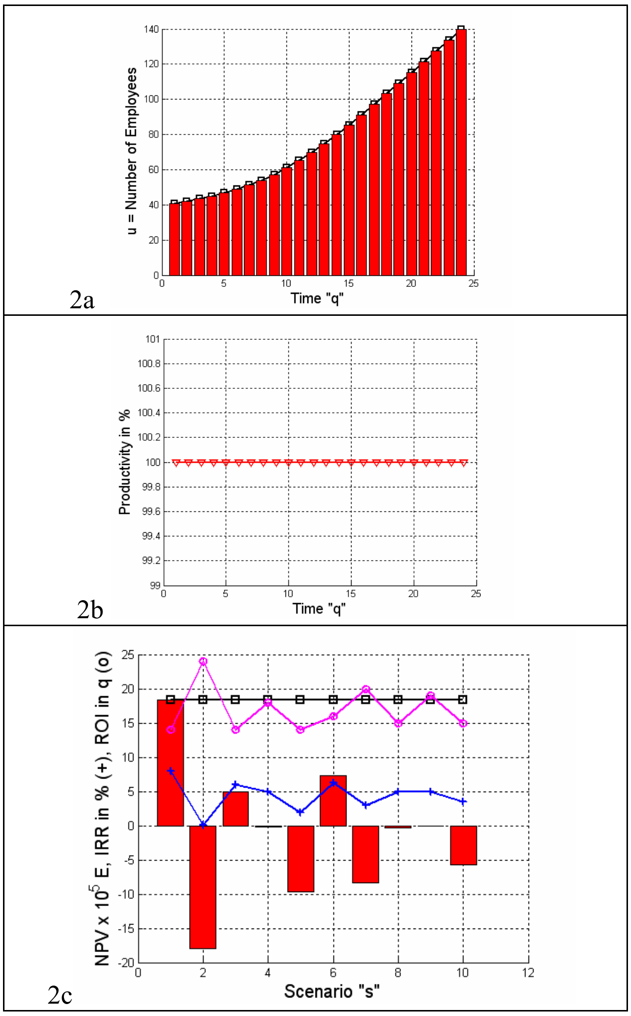


Figure 2. Computed optimum strategy $u_{s=1}$ (2a), productivity P (2b) and *NPV*, *IRR* and *ROI* values for s=1-10 (2c).

If the strategy $u_{s=1}$ is applied to all scenarios s=1-10, then the NPV(s), IRR(s) and ROI(s) values shown in Figure 2c are obtained. The minimum *NPV*-value is obtained for scenario 2 and is equal to

$$NPV_{s=2}= -1.8002e{+}006\ € \tag{15}$$

Applying now eq. (11), a new strategy $u_{s=1\text{-}10}$ (Figure 3a) is computed. $u_{s=1\text{-}10}$ is –as expected- different from $u_{s=1}$, as it serves not only one, but all 10 scenarios. The maximum minimum *NPV*-value is now reduced to:

$$\max(\min(NPV_{s=1\text{-}10}))=-1.3381e{+}005\ € \qquad (16)$$

from the value of eq. (15).

In order to facilitate the comparison of the basic scenario eq. (15) with other results, the $u_{s=1}$ strategy and the $NPV_{s=1}$ value for P=1 are displayed in the relevant Figures, characterized by curves with black squares.

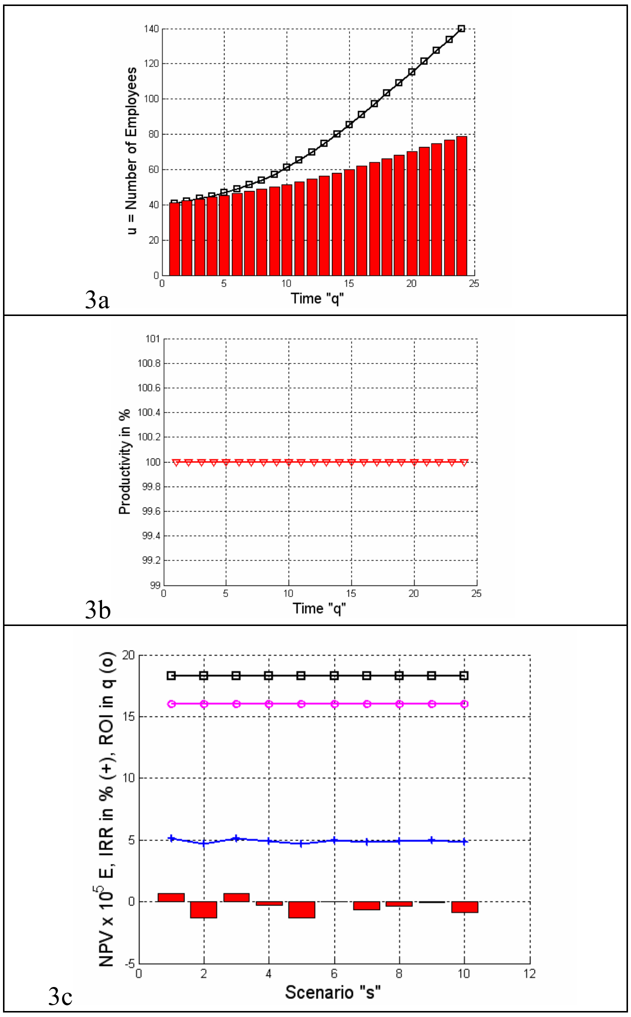


Figure 3. Case λ_1=1.0 and P_{L150}=0. Strategy $u_{s=1\text{-}10}$ (3a), productivity P (3b) and *NPV*, *IRR* and *ROI* values for s=1-10 (3c).

6 Variation of the Productivity *P*

In the following Figures, the λ_1, λ_2 and P_{L150} values are changed (P_{L30}=0). The results are displayed in the next Figures.

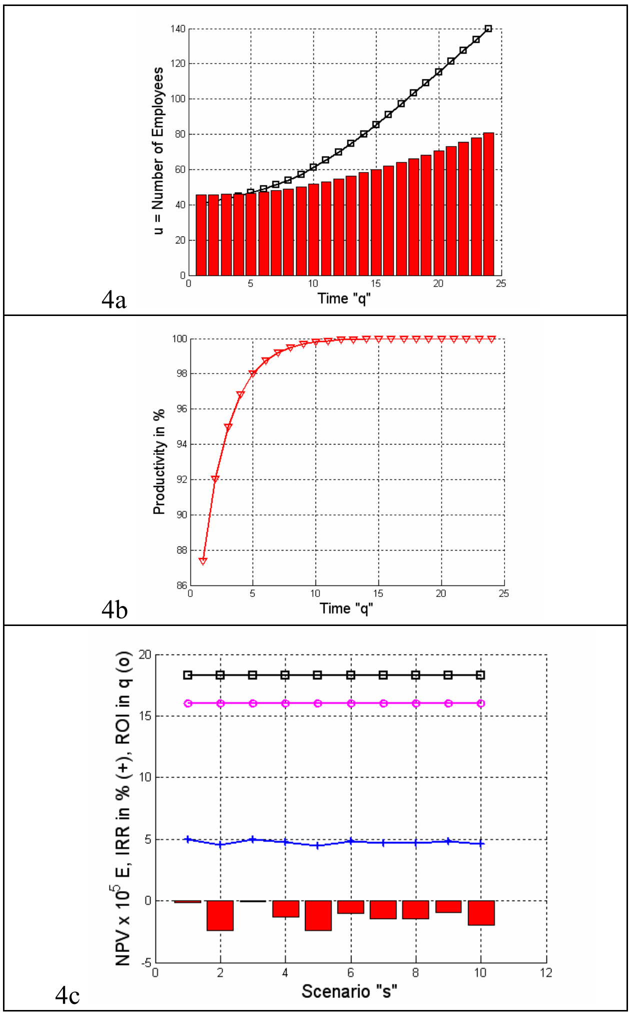
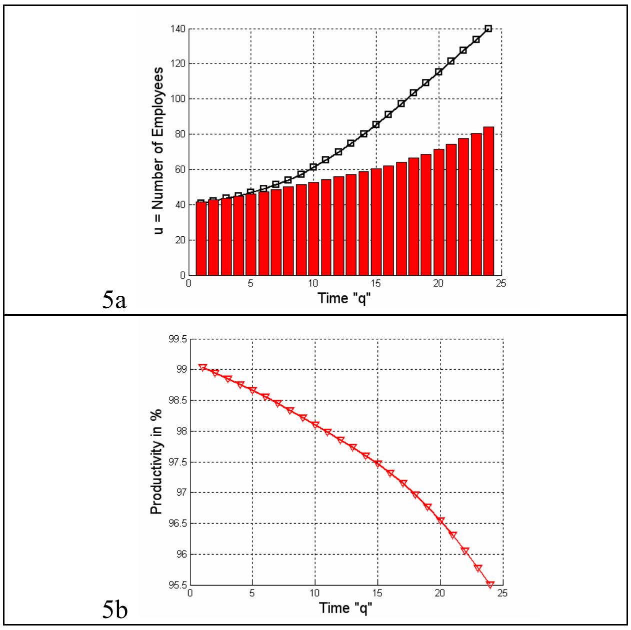


Figure 4. Case λ_1=0.8, λ_2=0.2 and P_{L150}=0. Strategy $u_{s=1\text{-}10}$ (4a), productivity P (4b) and *NPV*, *IRR* and *ROI* values for s=1-10 (4c).

$$\max(\min(NPV_{s=1\text{-}10}))= -2.3764e{+}005\ € \qquad (17)$$



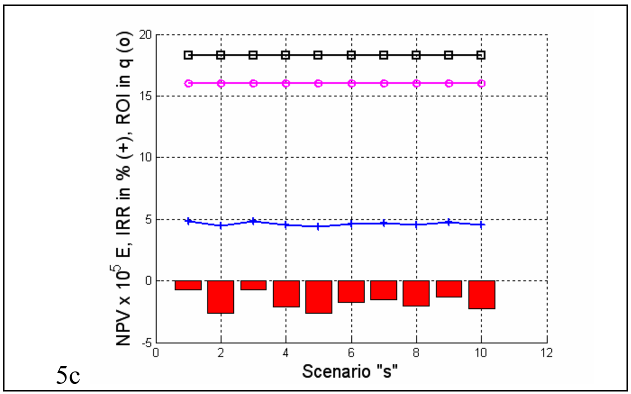


Figure 5. Case λ_1=1, λ_2=0.2 and P_{L150}=0.1. Strategy $u_{s=1\text{-}10}$ (5a), productivity *P* (5b) and *NPV*, *IRR* and *ROI* values for *s*=1-10 (5c).

$$\max(\min(NPV_{s=1\text{-}10}))= -2.6097e{+}005\ € \qquad (18)$$

From Figures 4-5 but also from Figure 6 we observe how the *P*-parameters influence the results. The max(min($NPV_{s=1\text{-}10}$)) value for *P*=1 decreases from -1.3381e+005 € to -3.7102e+005 € according to Figure 6 and to -5.8660e+005 € according to Figure 7.

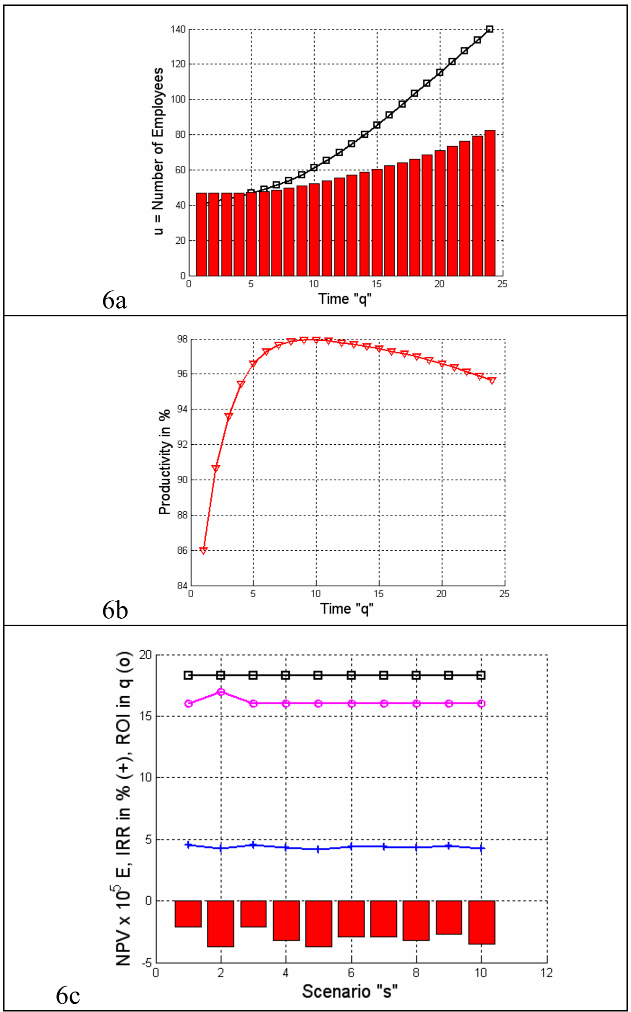


Figure 6. Case λ_1=0.8, λ_2=0.2 and P_{L150}=0.1. Strategy $u_{s=1\text{-}10}$ (6a), productivity *P* (6b) and *NPV*, *IRR* and *ROI* values for *s*=1-10 (6c).

$$\max(\min(NPV_{s=1\text{-}10}))= -3.7102e{+}005\ € \qquad (19)$$

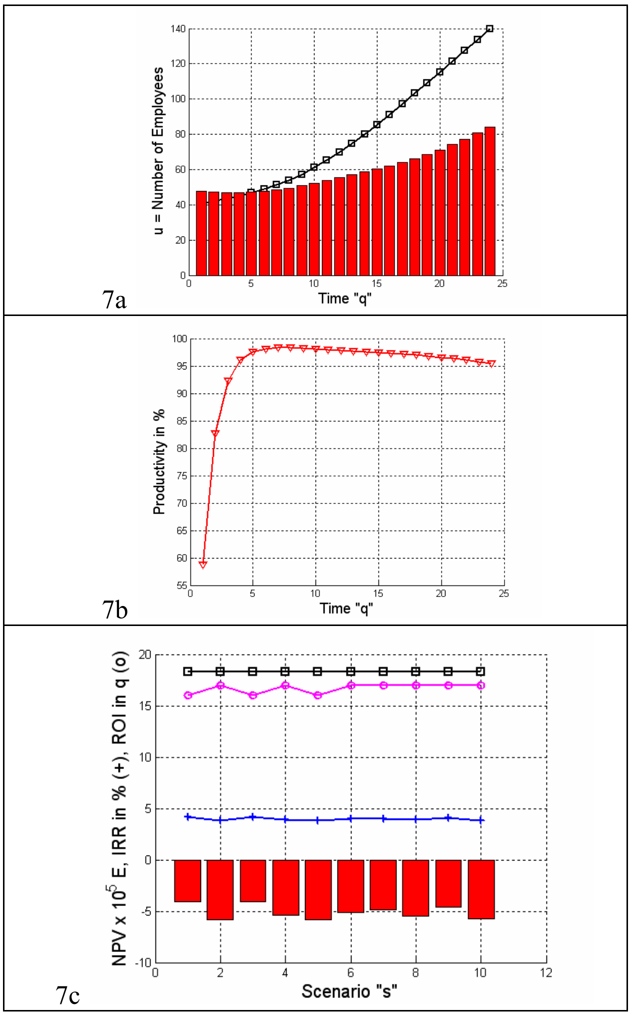


Figure 7. Case λ_1=0.0, λ_2=0.4 and P_{L150}=0.1. Strategy $u_{s=1\text{-}10}$ (7a), productivity *P* (7b) and *NPV*, *IRR* and *ROI* values for *s*=1-10 (7c).

$$\max(\min(NPV_{s=1\text{-}10}))= -5.8660e{+}005\ € \qquad (20)$$

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6 Conclusions

In this paper we applied the ‘min-max strategy’ to a production problem using a deterministic modeling of the possible expected returns (future scenarios) and a novel hybrid parameter optimization method for the computation of the optimal risk-minimum strategy.

The numerical results presented show that the learning effect and possible productivity losses greatly influence the risk of the planned production operation.

Finally, the method performs well and possesses an interesting potential for modelling more complex risk minimization problems.

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