Computerised Maintenance Decision Support System (MDSS) for Simulating and Selecting the most Cost-effective Production and Maintenance Solution: Case Study in FIAT/CRF, Italy

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ABSTRACT

To survive the hard international competition, it is necessary for many companies to enhance their competition positions through, for example; reducing production cost, and maintaining and improving production process and product quality for increasing the profit margin. In order to achieve these strategic goals, a tool for making investments in maintenance more profitable is developed, introduced, tested and discussed. This tool/module is one of the modules included by an innovatively new Maintenance Decision Support System (MDSS). Theoretical backgrounds are introduced, and software prototype (AltSim) for making the application on the daily basis easier and more cost-effective are developed, discussed and their functionalities are tested in FIAT/CRF, Italy. It is designed to support maintenance and production engineers to achieve cost-effective maintenance decisions. The major result of this study is development and testing of innovatively new tool/software module for simulating and selecting the most cost-effective production and maintenance solution. The major conclusion that can be drawn is; applying AltSim it is possible to identify and select the most cost-effective solution when there are several technically application solutions for the same problem.

1. INTRODUCTION

When it concerns problem analysis and solution identification and selection, from everyday experience is always possible to find several alternative solutions for the same problem. All these solutions can be technically applicable. But, they are not necessary equally cost-effective. In other words, different solutions of the same problem usually mean different investments, probably unequally payoff (Return on Investment in Maintenance (ROIIM)) and payoff periods, which are very important factors for deciding whether an investment should be considered or not. Maintenance related economic factors, such as; maintenance direct cost, production economic losses, maintenance investments, savings and results, influence in many cases a big share of a company income, [1]. Mckone and Weiss [2] cited that the amount of money spent company-wide on maintenance by du Pont (1991) was roughly equal to its net income. This is why selecting the most cost-effective solutions for the problems in producing companies will reduce the economic losses appreciably. The losses may spread over a wide area of the company’s activities, such as losses of production time because of unplanned stoppages, bad quality production, unacceptable working environment, failure related accidents, environment pollution, etc. This is why it is essential when treating a production problem, the solution should be cost-effective. In other words maintenance solutions for production problems should be cost-effective because maintenance is not just technical problem rather than economic problem [3]. The economic influence of maintenance in Swedish industry was estimated in Ahlmann [4] study to be around SEK 190-200 billion annually.

2. BACKGROUND AND DEVELOPMENT OF A SIMULATION MODEL

In Ljungberg [5], a case study was conducted at a Swedish car factory, Overall Equipment Effectiveness (OEE) was estimated to be on average around 55%. Also, according to the study done by Almström and Kinnander [6], the productivity of engineering manufacturing industry in Sweden was about 50%. Therefore, industry can increase its production capacity without the big investments that are required in new machinery if an efficient maintenance policy is implemented. It means smaller investments for enhancing the performance of maintenance are enough to increase the production capacity, profit and improve company competitiveness [7]. It is not that difficult to recognise maintenance role in maintaining and improving OEE through; maintaining availability, quality rate, performance efficiency & production rate, machine quality (technical specifications) as well as fulfilling delivering time schedule and reduce violation of environment. Maintenance role in the company business and its contribution in generating more profit can be clarified if we convert and measured all these factors to just one common well-understood scale, i.e. money. In this way, it will be possible to follow up the whole chain of the investment, i.e.

Capital invested- to- **Technical measures (results) in maintenance –** to- **Technical measures (results) in production-** to- **Economic measures (results) in the strategic level –** to – **Capital (Income)**

In this section we consider the same theoretical background and formulas used in MainSave[8]. These formulas are used for developing a new model that can be used for simulating alternative solutions, which are all suppose to be suitable technically, to distinguish the most cost-effective solution. In order to examine several alternative solutions for a particular technical problem to distinguish the most cost-effective, the model is constructed in the form of nine steps that are described below;

I. Developing a Reference Situation that mapping the real status of the production system using some of MainSave data such as, production rate, production period, number of failures, average stoppage period, number of short stoppages and its average stoppage period, and quality rate from two distinguished periods (Ibid).

II. Identifying and prioritising problem areas in the production and maintenance processes for deeper analysis.

III. Problem technical analysis is important to illustrate the root-causes behind damage initiation, damage developing mechanisms, and for suggesting relevant alternative solutions to solve the problem. For example, using different condition monitoring (CM) technologies, new analysis software program, training courses for better usage of the available maintenance technologies or to enhance the quality of maintenance actions. For this model, we use just three solutions to reduce the number of alternative and to indicate three different levels of confidence; Acceptable, Good and Very Good technically, which are weighted by Max. 60%, Max 80% and Max. 100%, respectively.

IV. Assess the approximate investing capital (and the depreciation period) required for each alternative solution mentioned above in III, which may cost unequally.

V. Examination of the effect of each solution on the production and maintenance processes should be done properly through anticipating the effects of every solution on the performance of production and maintenance processes that are measured using the same data have been considered in the Reference Situation in I above, to highlight its ability in, e.g.;
   - detecting problem symptoms at an early stage,
   - eliminating unplanned and unnecessary stoppages,
   - prolonging the lead-time, reducing bad quality production &
   - reducing failure related accidents.

VI. Converting all these technical effects to economic measures.

VII. Compare the capital invested for each solution/technique and the payoff (savings).

VIII. Assess total savings/profit and ratio of savings to investment for each alternative solution.

IX. The most cost-effective solution is that which acquire higher profit. The ratio of savings to investment can also be used to distinguish the most cost-effective, but this will not necessary introduce the one with the highest profit.

3. DEVELOPMENT OF SOFTWARE PROTOTYPE

Applying the model developed above manually is very much labour and time demanding. Therefore, software prototype AltSim is developed using C-sharp language to support the end user for daily application for selecting the most cost-effective solution when there are several alternatives. The alternative solutions suggested for solving a problem influence all the categories of savings/losses stated in the Reference Situation, i.e. all the white coloured boxes in Alternative 1, 2 & 3, as shown in Fig.2. To run the AltSim software, “Segment”, “Profit margin”, “Reference period” & “Anticipated period” should be specified. When the button “Load” is clicked, the data required to describe the Reference Situation will be retrieved from MIMOSA database, Fig.1. Fig.2 shows Alternative solution 1, where all the data shown in the grey- coloured boxes are similar in all three alternatives and are retrieved as a Reference Situation from MIMOSA database. User-interface of Alternative 1, 2 and 3 are identical except that concerning the data that should be anticipated in the white coloured boxes are different for different Alternatives. When the information required for Alternative 1, 2 and 3 is anticipated, AltSim will automatically suggest the most cost-effective alternative solution when pushing the button “Results”, Fig.3. The data required for running AltSim are: real data representing the Reference Situation and retrieved from the database, i.e. database datasets that are shown in the grey coloured boxes, except the profit margin per each item, ton, meter or cubic meter, etc. which should be entered manually. Also, we manually enter the anticipated data, such as the number of failures when using a particular solution/CM technology during the anticipated period, e.g. one year. These data are should be feed in the white coloured boxes, see Fig.2, which are:

- o Reference period; the period during which the data representing the current situation are collected
- o Anticipated period for comparison, e.g. one year
- o Total investment in maintenance for performing the Alternative
- o Depreciation period (period of the investment life length)
- o Production time and rate during the anticipated period
- o Type of investment and its confidence level.
- o Anticipated numbers of failures and short stoppages.
- o Anticipated average time of these stoppages and quality rate

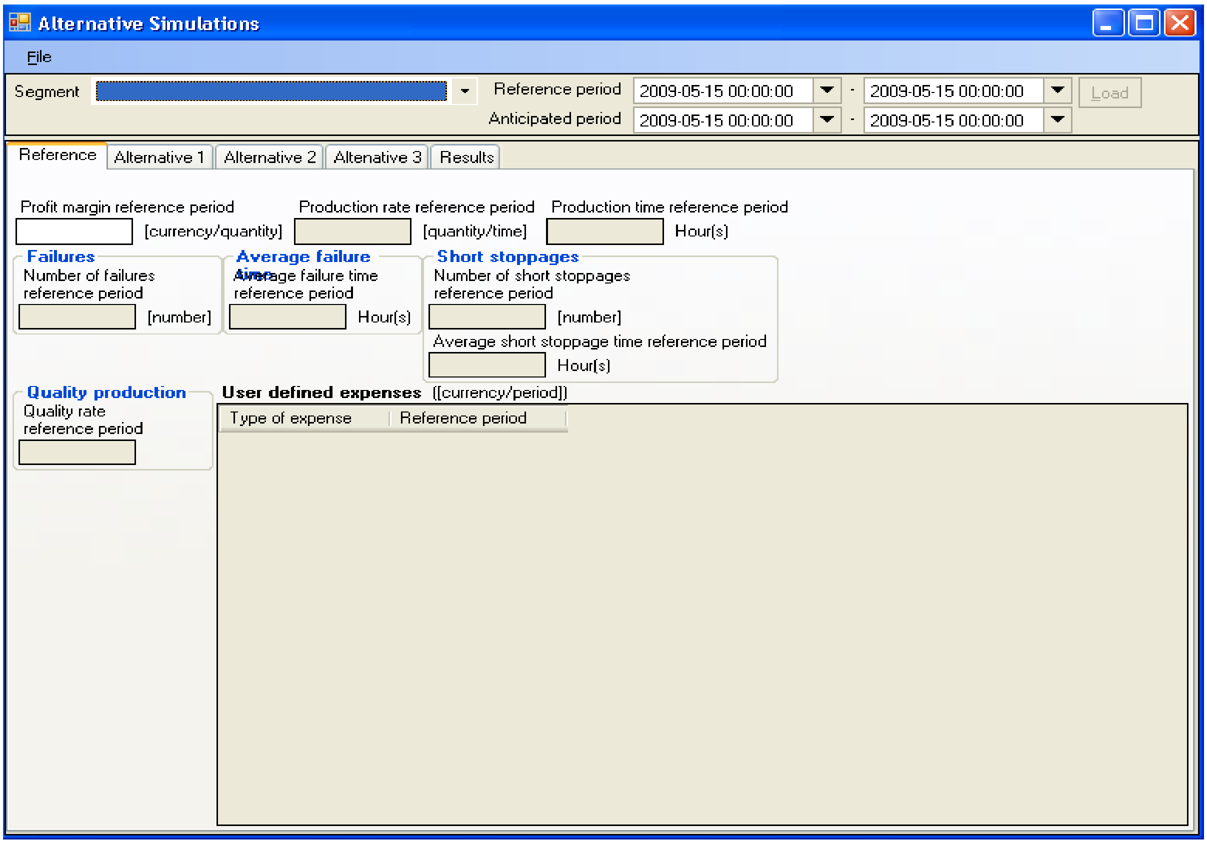

Fig.1. User-interface of AltSim software, Reference Situation.

The rest of the information shown, such as savings, investment per period and ratios are assessed by AltSim. The data described by database datasets are;

- o Data regarding one production machine and product.
- o The data collected cover two production periods, i.e. before (Reference period) and anticipated period, i.e. after an improvement in the maintenance or production process using one of the Alternative solutions is done.

4. AltSim TEST

The major objective of applying software module AltSim is to simulate different technically applicable alternative maintenance solutions for a particular problem for distinguishing the most cost-effective. The industrial data required for conducting AltSim test were gathered from FIAT/CRF are shown in Fig.s 4a and b, and Fig.5. The data are; theoretical cycle time, planned production time, stoppages and event cause category, and bad quality production. The only data that have been feed in the white boxes manually are the profit margin. AltSim analysis results of simulating three alternative solutions shown in Fig.6a,b,c & d. In Fig.6a shows the reference data that MDSS has retrieved from the database. The machine at FIAT/CRF that was considered for MDSS test is a CNC-milling machine. It produces engine heads. The operation that is performed by the machine is milling. This machine is considered to be a bottleneck in the production line which makes it critical for the whole production process. The data were collected at two periods (8th of Jan. 2007 – 8th of June 2007) and (9th of June 2007-8th of Jan. 2008). Failure data have been collected with high precision.

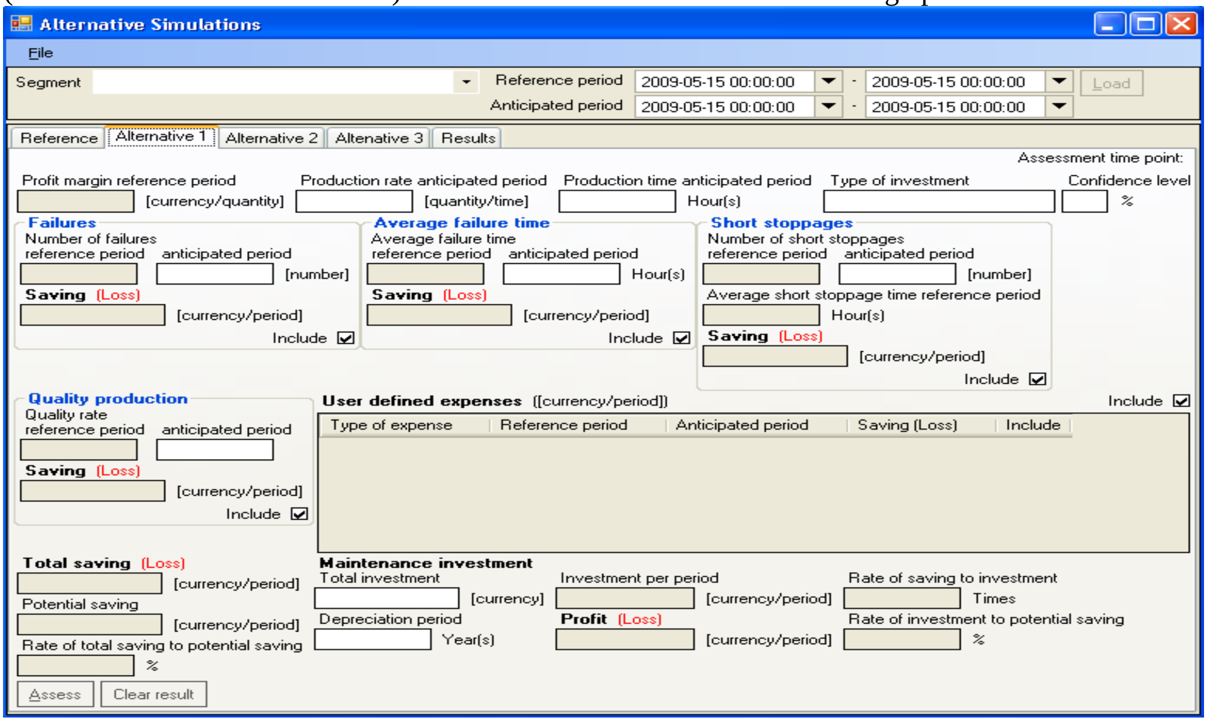

Fig.2. User-interface of AltSim software, Alternative 1.

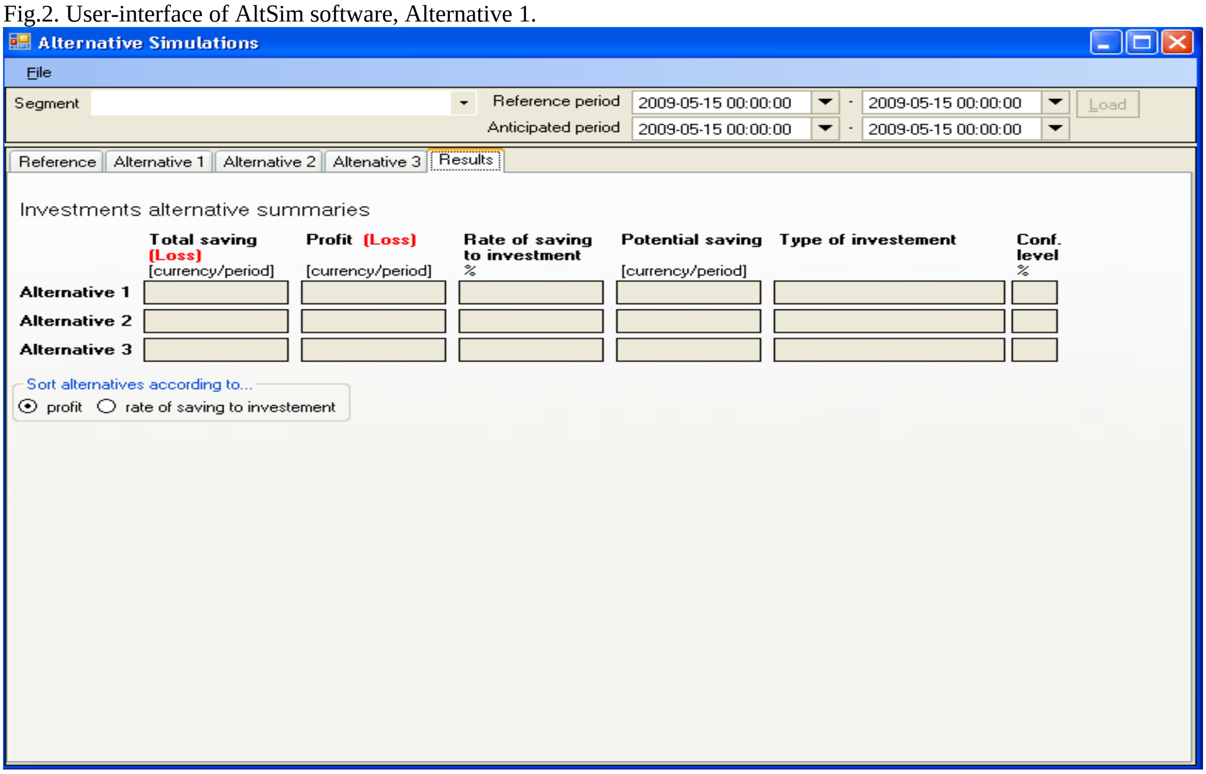

Fig.3. User-interface of AltSim software, Results.

Model process model specific

Model	<Set	Process model	<Set	Theoretical cycle time (seconds)
TEKOP10 [Machinery]	TEKOP10 [Machinery]	TEK-OP10 [Production Process Input/Output]	TEKOP10 [Machinery]	174
TEKOP10 [Machinery]	TEKOP10 [Machinery]	JTD Engine Head [Production Process Input/Output]	TEKOP10 [Machinery]	274,8

Record: 1 of 2

Fig.4a. Production theoretical cycle time.

Production

Segment: JTD Engine Head Line [Machinery, Industrial Production]

Process model	<Set	GMT production start	GMT production end	Planned production time (hours)
JTD Engine Head [	TEI	2007-01-08	2008-01-08	4880

Record: 1 of 1

Fig.4b. Production time.

Production follow-up

Production: JTD Engine Head [Production Process Input/Output] on JTD Engine Head Line [Machinery, Industrial Production] at 2007-01-08

GMT follow-up	Actual production quantity	Defective production quantity
2007-03-31	17203	425
2007-06-30	16401	408
2007-09-30	13702	349
2008-01-08	16622	448

Record: 1 of 4

Fig.5. Production follow up data.

FIAT/CRF personnel suggested three alternative solutions using different CM systems for solving the problem of the stiffener which was behind a big part of the failures:

Alternative 1

- 3x vibration sensor for stiffener system and cast blocking system
- 1x (alternative to existing) laser for cast positioning
- Prognostic method for stiffener and cast blocking sensors
- The investment required for this CM system is estimated to be 30000 units
- Depreciation period is estimated to be 4 years

Alternative 2

- 1x vibration sensor for stiffener system
- Prognostic method for stiffener and cast blocking sensors
- The investment required for this CM system is estimated to be 15000 units
- Depreciation period is estimated to be 4 years

Alternative 3

- Installation of 1x sensoring (alternative to existing) laser for cast positioning and training program
- The investment required for this CM system is estimated to be 10000 units
- Depreciation period is estimated to be 4 years
- The data describing the reference situation are shown in Fig.6a, which is completed by the profit margin (95 units). The impact anticipated out of all the three investments are specified in Alternative 1, 2 and 3 and shown in Fig.s 6b, c and d, respectively. Based on the long term economic results of the anticipated impacts of the three investments (alternatives), AltSim motor has selected alternative 1 as the most cost-effective although it demands bigger investment, Fig. 6e.

The final conclusion that can be drawn is that the size of the investment cannot be used as a criterion to judge the cost-effectiveness of an investment in maintenance. To judge the cost-effectiveness of investments in maintenance we should consider the long term maintenance economic payoff, i.e. Return on Investment in Maintenance (ROIIM). The comparison between these three alternatives can be done with respect to either the potential total profit that will be generated or the potential rate of the saving to the investment. Notice that the most cost effective alternative can be different based on which criterion is used. In this case we used the profit absolute value to distinguish the most cost-effective maintenance solution. Notice that the black/red coloured numbers associated with saving and profit means savings, profit/losses respectively.

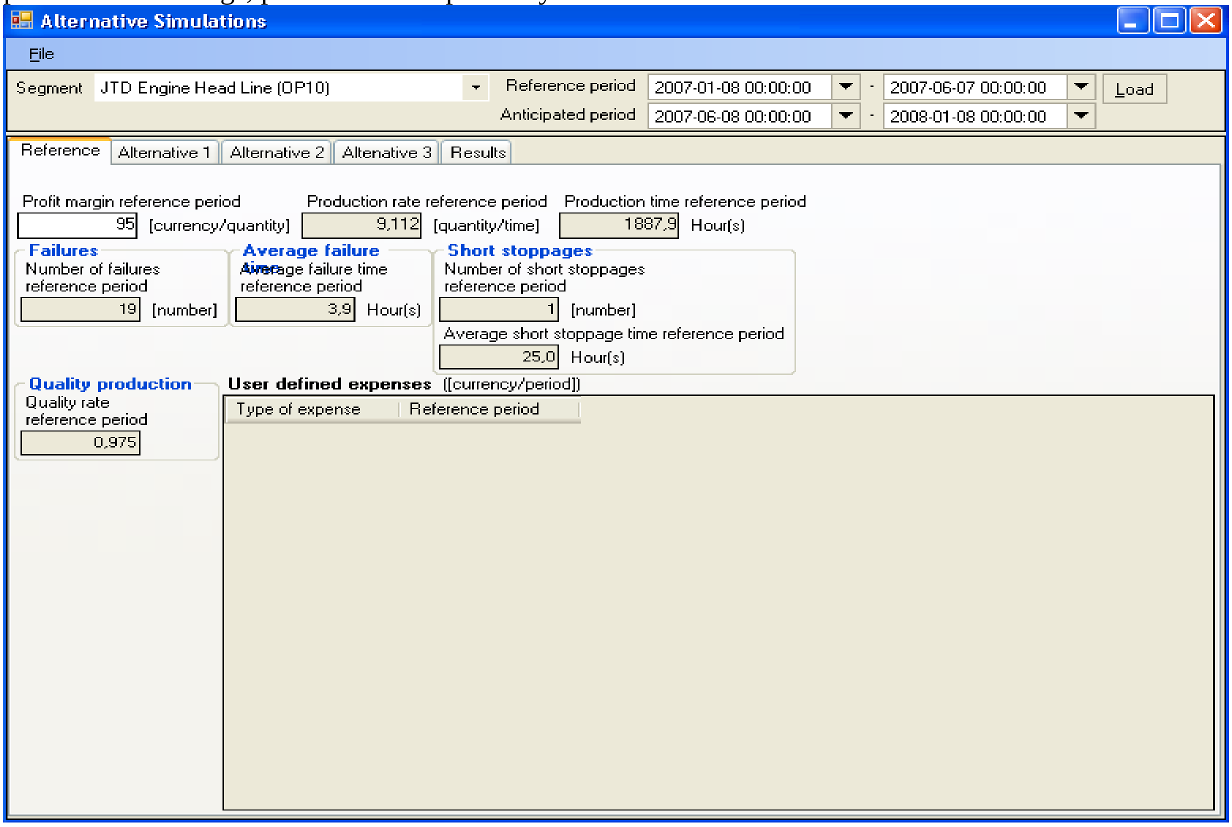

Fig.6a. User-interface of the software module AltSim; test results (Reference data)

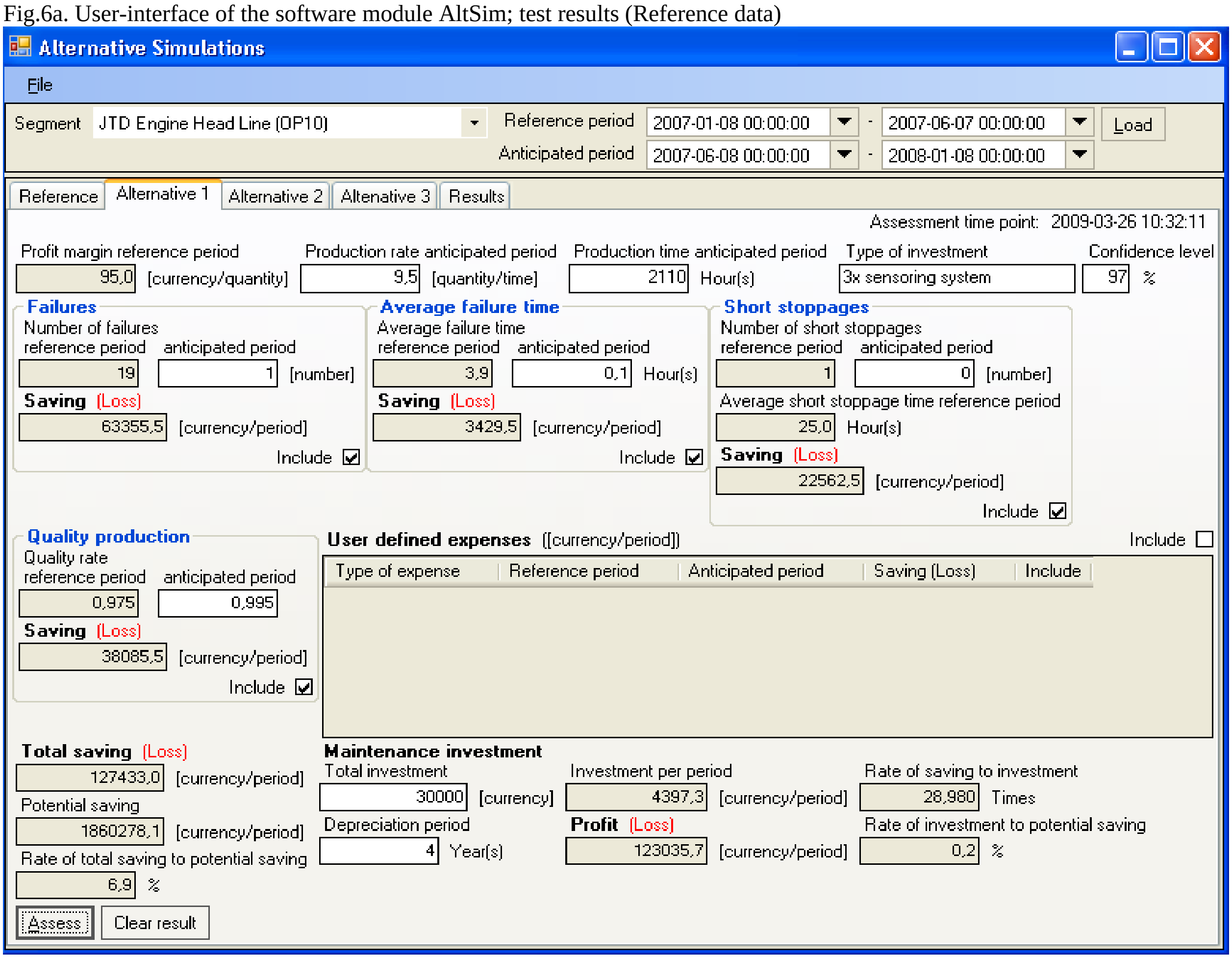

Fig.6b. User-interface of the software module AltSim; test results (Alternative1)

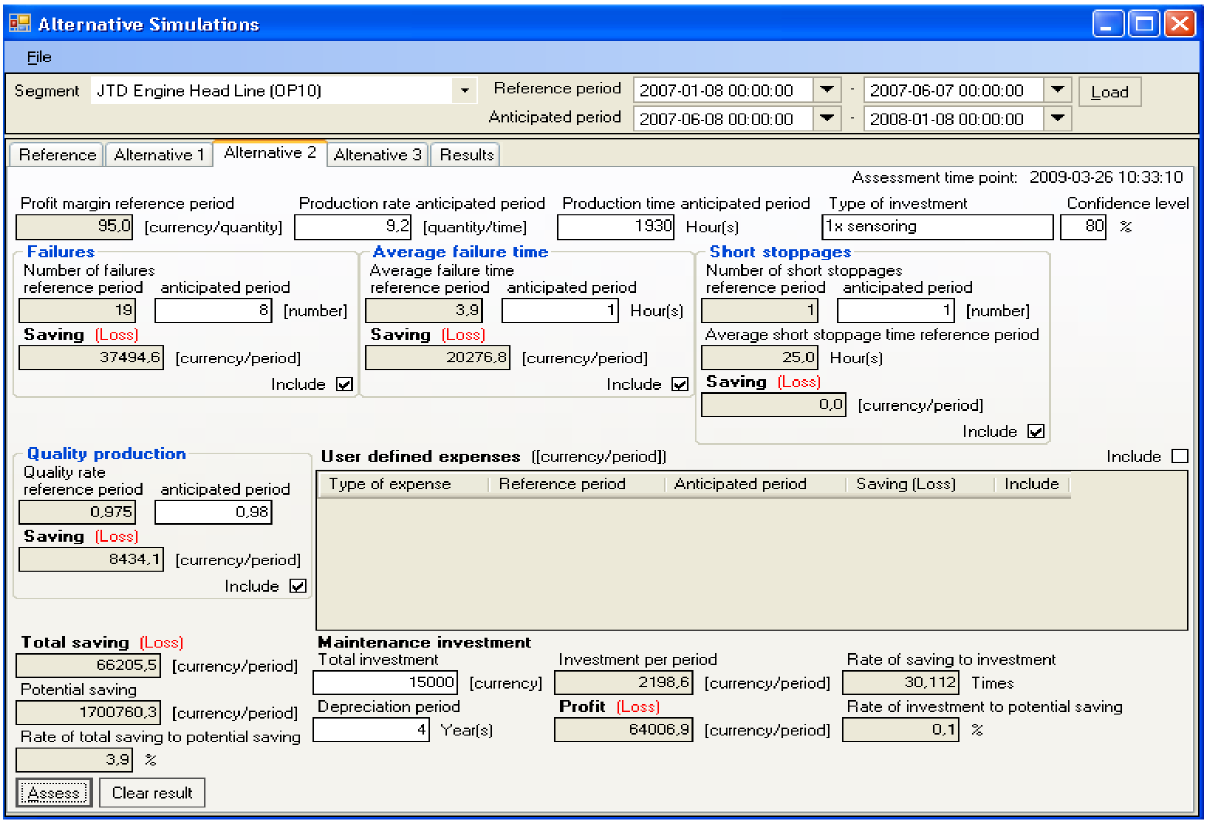

Fig.6c. User-interface of the software module AltSim; test results (Alternative2)

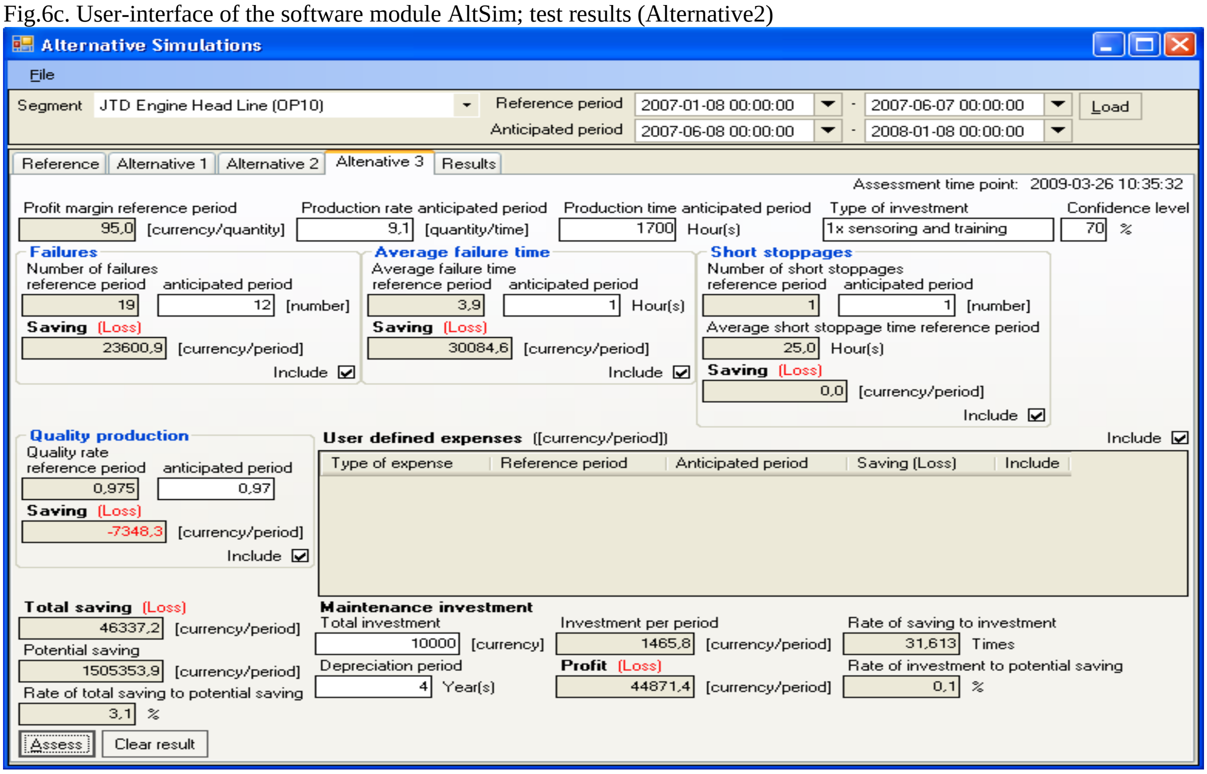

Fig.6d. User-interface of the software module AltSim; test results (Alternative3)

5. RESULTS, DISCUSSIONS AND CONCLUSIONS

When the profit margin of a plant decreases, the need for reliable and efficient maintenance policy becomes more important, because it will be more important to reduce the economic losses, i.e. pressing down production cost per high quality item, ton or meter, and consequently increases the profit. The major result of this study is the development of a new model and software prototype (AltSim) for enhancing maintenance cost-effectiveness, performance and economic impact on company business through simulating relevant alternative solutions for one problem and select the most cost-effective maintenance solution. The test of the model has shown clearly the potentials and the benefits of application. Using AltSim, it is possible to identify several applicable solutions, simulate their effects on the company business and select the most cost-effective. It is important to enhance production and maintenance processes' performance in both tactical and strategic levels for fulfilling company's strategic goals in continuous and cost-effective improvement of its profitability and competitiveness. These results are hard to achieve using available tools and techniques even if the data required are available. AltSim is developed using new and flexible model that can be accommodated to each production process without big difficulties for enhancing its accuracy. It provides better data coverage and quality which are essential for improving knowledge and experience in maintenance and thereby aid in increasing the competitiveness and profitability of a company.

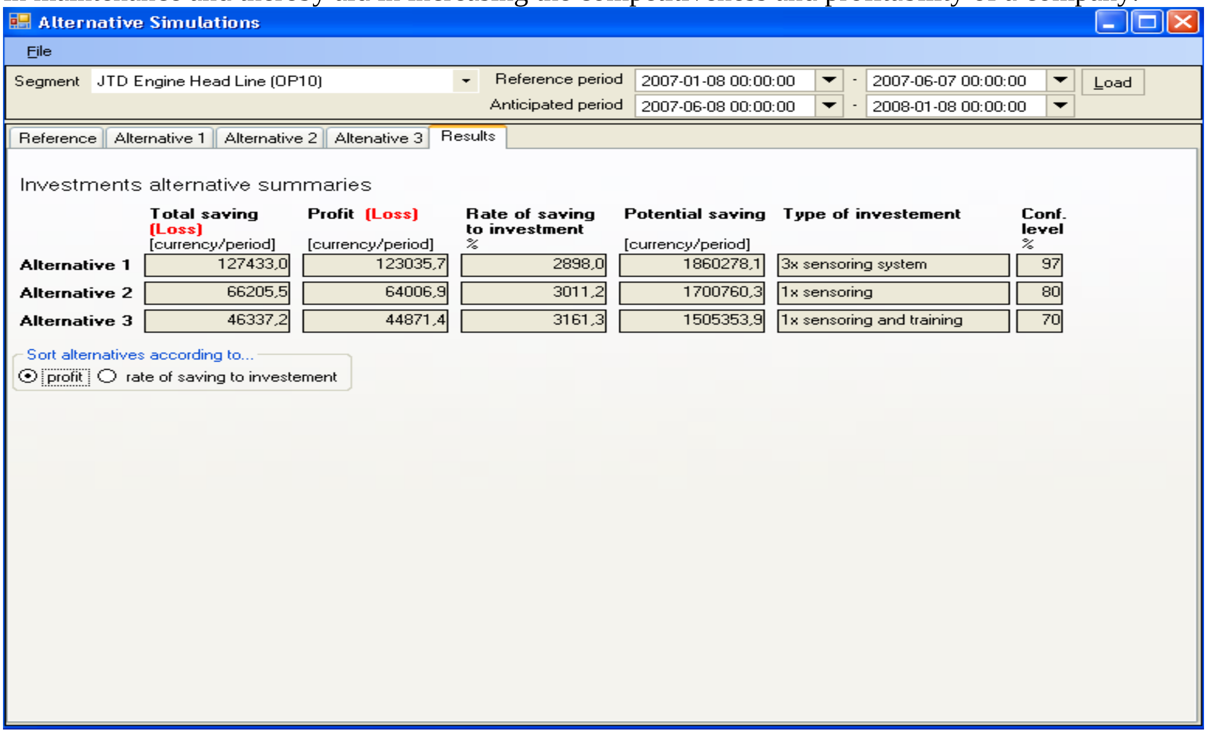

Fig.6e. User-interface of the software module AltSim; test results (Results of the selection)

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