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SOFTWARE PERFORMANCE EVALUATION OF A COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM: A STATISTICAL BASED COMPARISON

OCENA DZIAŁANIA OPROGRAMOWANIA KOMPUTEROWEGO SYSTEMU ZARZĄDZANIA UTRZYMANIEM RUCHU. BADANIA STATYSTYCZNO-PORÓWNAWCZE

In today highly competitive markets, application of maintenance management systems is un-avoidable. However, in refinery environments due to huge investment amount of operating systems, applying advanced maintenance management systems (Such as Computerized Maintenance Management System which is called CMMS) is increasingly seems to be a crucial task. In order to implement high performance CMMS software, the existing ones should be analyzed. In this paper, performance of two CMMS related software entitled IFS™ and MAINTA™, are introduced, analyzed and compared using significant statistical analysis with a case study in a refinery. The results of both hypothesis testing and economical study finally proposed the MAINTA™ software.

Keywords: *CMMS, statistical analysis, economic study, maintenance management.*

Na dzisiejszych, niezwykle konkurencyjnych rynkach, zastosowanie systemów zarządzania utrzymaniem ruchu jest niezbędne. Przykładem są zakłady rafinerii, w których, ze względu na wysokie sumy inwestowane w systemy operacyjne, zastosowanie zaawansowanych systemów utrzymania ruchu (takich jak Komputerowy System Zarządzania Utrzymaniem Ruchu CMMS) wydaje się coraz bardziej istotnym zadaniem. Aby jednak wdrożyć wysokiej klasy oprogramowanie CMMS, należy najpierw przeanalizować istniejące programy. W niniejszym artykule, przedstawiono, przeanalizowano i porównano za pomocą analizy statystycznej działanie dwóch programów typu CMMS o nazwach IFS™ oraz MAINTA™. Analizy oparto na studium przypadku przeprowadzonym w rafinerii. Wyniki testowania hipotez oraz analizy ekonomicznej wyłoniły oprogramowanie MAINTA™ .

Słowa kluczowe: *CMMS, analiza statystyczna, analiza ekonomiczna, zarządzanie utrzymaniem ruchu.*

1.Introduction

CMMS are using increasingly in control and maintenance management for equipments in servicing and producing in several industries. The principals of CMMS used for the first time in hospital maintenance system due to importance of medical equipments health, and also according to the fact that bad results in hospital maintenance could lead many people to dead. Currently, private companies realized the importance of maintenance management systems as a tool for enhancing the performance of maintenance and repairing systems. Emerging small and private computers in past years caused to popularity of these systems among companies. As the computer skills of maintenance and equipment personnel became grater, the respect to such systems as an attractive option is now greater than before. Thus, investment on CMMS by different advanced organizations increasingly grows. Typically, these systems are designed in a manner that provide significant support the requirements of documentations control through ISO 9001:2008 and as a part of philosophy of productivity maintenance can be also applied. Many of the existing CMMS have the same efficiency, and common components which had been provided by the most of CMMS software including several main modules (figure 1) that cover the basic activities of maintenance and repairing systems.

Krouzek [6] presented a case study of the development and implementation of the Czechoslovak UNDP/UNIDO project "Application of Modern Computerized Maintenance System". He highlighted the economies achieved in terms of both tangible benefits and costs incurred. Also he claimed that the general maintenance functions were outlined and their incorporation into the project activities was described. He expressed the evaluation of multiple aspects of the CMMS is provided with particular attention given to system modularity and integrity,

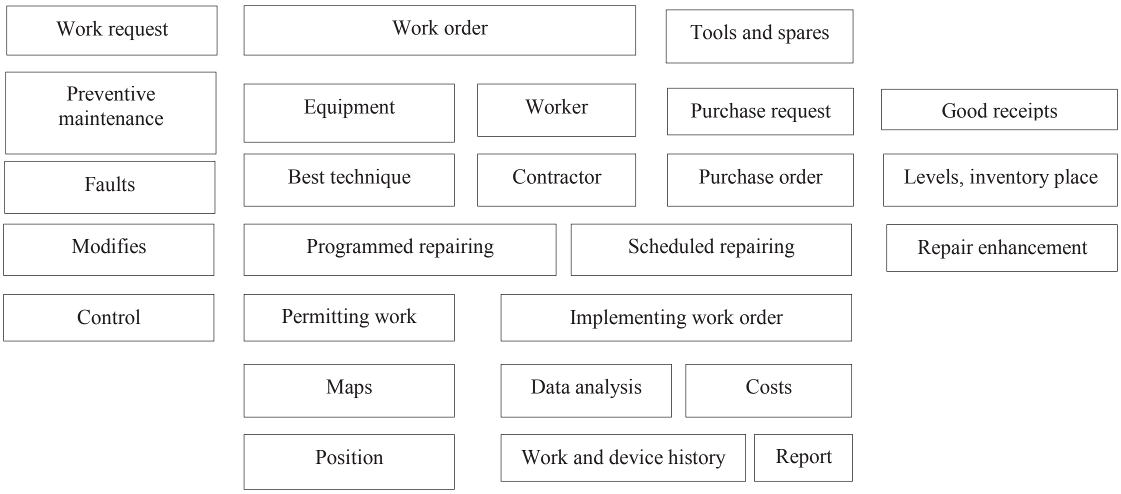

Figure 1. Major components of CMMS

stepwise development and implementation, and hardware and software support.

Jones and Collis [4] obtained an overview of the use of computers in maintenance management to inform the maintenance management systems could be beneficial according to principal application of re-engineering. Fernandez *et al* [2] discussed the role of CMMSs as a powerful tool necessary for obtaining information from raw data and support the decision-making process. Furthermore, a CMMS has been designed, developed, customized and implemented for a disc brake pad manufacturing based company in England. In addition, a maintenance maturity grid has been proposed to support the CMMS implementation. The implemented CMMS aimed to reduce total downtime and frequency of failures of the machines by improving the efficiency and effectiveness of the maintenance force. Swanson applied Galbraith's (Organization Design, Addison-Wesley, and Reading, MA) information-processing model to study how the maintenance function applies different strategies to cope with the environmental complexity. Also he expressed, based on data from a survey of plant managers, the analysis shows that maintenance responds to the complexity of its environment with the use of CMMS, preventive and predictive maintenance systems, coordination and increased workforce size (Swartone [13]). Gabbar *et al* [3] presented the detailed system design and mechanism of improved RCM (reliability-centered maintenance) process where integrated with CMMS. The proposed approach was integrated with design and operational systems and consolidates some successful maintainability approaches to formulate an efficient solution for optimized plant maintenance system. The major components of the enhanced RCM process are identified and a prototype system is implemented as integrated with the various modules of the adopted CMMS (MAXIMO). They also run a case study to show the effectiveness of the proposed RCM-based CMMS solution in optimizing plant maintenance over the traditional approaches (Gabbar *et al* [3]). O'Donoghue and Prendergast [11] examined the basis of various maintenance management strategies used to date through an international manufacturing environment. These strategies assist the maintenance function and enable the maintenance process to be optimized. Also, they expressed special focus was given to CMMSs, indicating how this particular strategy was successfully implemented in a medium sized Irish textile manufacturing company. Labib [8] proposed to implement the holonic concept in maintenance systems. The main features of the holonic concept were set using fixed rules and flexible strategies. In this paper, the author attempted to put these concepts into the maintenance systems through manufacturing environment. He then discussed holonic concepts with emphasis on applications in maintenance of manufacturing systems. Braglia et al [1] provided a structured methodology to permit an optimal selection of the best (CMMS) software within process industries. They proposed a robust approach, structured and useful in practice, for the selection of CMMS software, which takes into account multiple criteria and overcomes the limitations of subjective decisions. Rusin and Wojaczek [12] worked on analysis of maintenance options for power machines and equipment. The assumed criterion for the selection of the range of repair works was the level of technical risk posed by a given facility below the accepted allowable level. For the assumed maintenance periods minimal sets of equipment were determined. Kundler [7] discussed the maintenance parameter based on the statistical analysis, and results for further operational were used in his paper. The statistical analysis was used for planning process of the product management. The analysis of different incident types and their characteristics based on the collected statistical maintenance data over operational period from 2001 to 2006 was performed. Kans [5] developed a conceptual model for identifying maintenance management including IT requirements, with its practical application in a process for the IT requirements for maintenance management. Moreover, he promoted the use of a structured procedure for the identification of IT requirements for maintenance management.

Generally, main objective of applying a CMMS is managing advanced maintenance system, including and precise investigating, precise implementing of repairing in an operating system, estimating the repairing costs and finally reducing the costs and relevant idle times. In this respect, different companies including IBM®, SAP®, IFS®, Apave® came to this field and all of them following a unique objective, assuring the buyer in order to cost and time saving. Manbachi *et al* [9] presented a new comprehensive solution for maintenance scheduling of power generating units in deregulated environments by applying an annual independent market. The solution was obtained by using a Genetic Algorithm (GA) and a Monte-Carlo Simulation (MCS). In a deregulated environment, each Generation Company (GENCO) desired to optimize its payoffs, whereas an Independent System Operator (ISO) had its reliability solicitudes. Michele and Daniela [10] identified the challenges for maintenance, repair and renewal planning faced by asset owners and managers. Integration with existing systems such as CMMS, Geographic Information Systems, is seen as the largest challenge for developing and using decision-support tools in the area of asset management. Wenyuan and Wenbin [14] presented a modeling study of optimizing the preventive maintenance (PM) interval of a production plant within the context of a case study. They obtained an estimated mean number of the defects identified at the PM epoch by the plant maintenance technicians. Once the parameters of the model were known, a PM model was proposed to optimize the expected downtime per unit time with respect to the PM interval.

2. Two challenging CMMS software:

2.1. MAINTA ™

The MAINTA software initially developed by APAVE which is a French based company . This software has some helpful features for planning and controlling the maintenance operations, and also for creating necessary facilities and equipments in logistic and supporting services, stores control and creating necessary feedbacks for providing manager reports. Additionally, some other important features of this software are:

- Implementing and structural properties
- Repairing capabilities and properties
- Logistic and goods capabilities and properties

The MAINTA™ system was designed throughout three structures: data base and server program (which can be installed on a central server), and a user that by an installed program on a PC can connect to the server. The server program can be installed on different servers and even on multiple servers if the number of users has a growth. The network managers and users need to special training terms before making any change in system. Also the store management (reserve, purchase, reception and etc), the work order management (the planned preventive maintenance work order, defective work order, annual work order, the service work order), reporting system (graph and issue results to Excel files), all represents advantages of Mainta ™.

2.2. IFS

The IFS ™ (Industrial and Financial System) can be installed in an operating system. The IFS Navigator opens the following items:

- Equipment: In this part you can see codes, information, properties and spare pieces related to apparatus and machinery.
- Work order management: In this part, it can trace the faults reports and work orders.
- Documentation: In this part, you can see all information about site including: onshore information, offshore information, repairing information and methods, repairing reports, evidence and information of HSE (Health Safety Environment).
- Creating the fault report: In IFS you can see work orders and preventive maintenance easily and you can realize that currently a work order is in which stage and status. The reports and costs are including those that can be investigated easily and viewing the documents and maps can be done easily.

3. IFS™ and MAINTA ™ Comparison using statistical analysis

In this section, we addressed the IFS™ and MAINTA™ features by evaluating form that are completed using expert judgments and analyzed by SPSS ™ as statistical analysis software.

3.1. Descriptive Statistical analysis

In this section, initially descriptive statistical analysis of the case under consideration in this paper is given in Table 3.

Based on the above table, it can be concluded that almost about 36% of participants in this research selected IFS™ and about 64% selected MAINTA™.

Table 2 also addressed the useful descriptive statistician data which are related to basic information in questions.

Based on the above table it can be concluded that the mean scores (participants views) obtained in basic information for MAINTA™ software is a little greater than for IFS software. Also the scores of standard deviation for MAINTA software is 4.28 and for IFS software is 5.08, and in other hand, the mini-

Table 1. Frequency distribution of participants based on maintenance and repairing software

Software	Frequency	Percent	Valid percent	Cumulative percent
IFS ™	10	35.7	35.7	35.7
Mainta™	18	64.3	64.3	64.3
Total	28	100	100	-

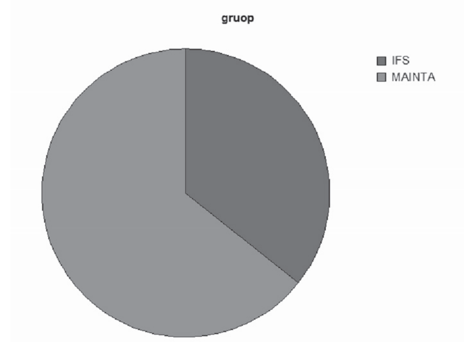

Fig. 2. The frequency percent distribution of participants, base on using the maintenance and repairing software

Table 2. Summary of statistical results related to basic information section

Software	Mean	Median	Standard deviation	Maximum	Minimum	Variance
IFS™	11.4	9.5	5.08	19	5	25.82
Mainta™	11.67	12.5	4.28	18	6	18.35

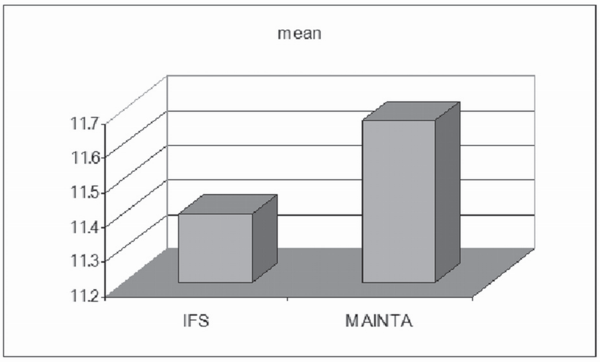

Fig. 3. The mean scores of participants in basic information section

mum and maximum scores are belong to IFS software that are 5 and 19 from 20, respectively.

Table 3 addressed the useful descriptive statistician data that are related to basic information in questions.

It can be concluded based on the above table that the mean scores obtained for MAINTA software is equal to 10.72 and for IFS software is equal to 13.1 in planning section. Also the standard deviation for MAINTA software is 5.72 and for IFS is 3.67 and in other word the variances for MAINTA and IFS are 32.68 and 13.43, respectively.

Table 3. Summary of statistical results related to planning section.

Software	Mean	Median	Standard deviation	Maximum	Minimum	Variance
IFS™	13.1	12.5	3.67	19	8	13.43
Mainta™	10.72	11.5	5.72	18	0	32.68

It can be concluded based on the above table the mean scores obtained for MAINTA software is equal to 10.89 while for IFS software is equal to 13.6. Also the standard deviation for MAINTA software is 4.66 and for IFS is 3.27 and in other word the variances for MAINTA and IFS are 72.21 and 10.71, respectively.

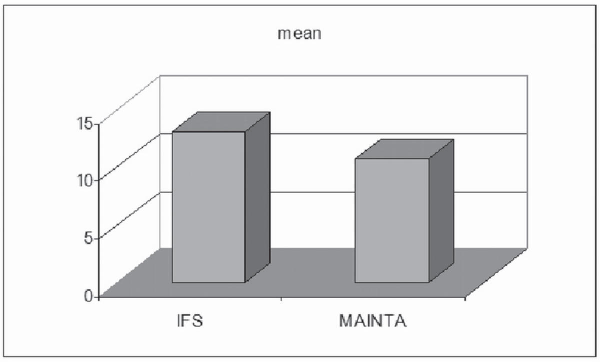

Fig. 4. The mean scores of planning section

Table 5. Summary of statistical results related to reports sections

Software	Mean	Median	Standard deviation	Maximum	Minimum	Variance
IFS	13.6	12.5	3.27	19	10	1071
Mainta	10.89	12	4.66	17	0	21.75

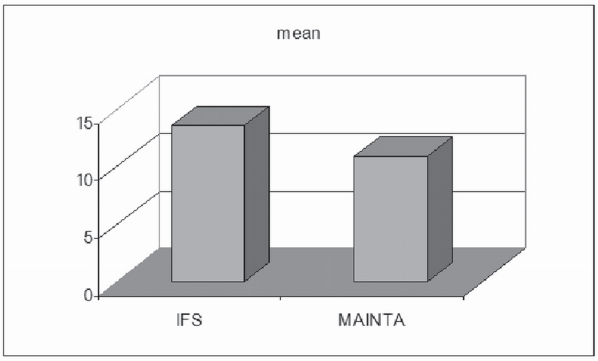

Fig. 5. The mean scores of reports section

It can be summarized based on the above table that the mean scores obtained for MAINTA software is equal to 12.3 and for IFS software is equal to 14.56 in other requirements section. Also the standard deviation for MAINTA software is 3.76 and for IFS is 4.32 and in other word the variances for MAINTA and IFS are 14.14 and 18.68, respectively.

Table 6. Summary of statistical results related to other requirements.

Software	Mean	Median	Standard deviation	Maximum	Minimum	Variance
IFS	14.56	11.5	4.32	20	6	18.68
Mainta	12.3	15.5	3.76	20	6	14.14

3.2. Comparison based on hypothesis Testing:

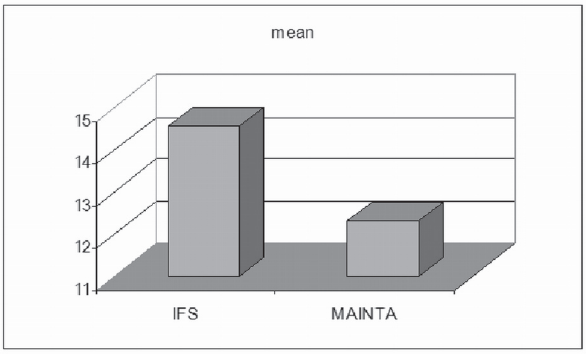

Fig. 6. The mean scores of other requirements section

3.2.1. The first hypothesis:

Assumption H0: There is not a significant difference between viewpoint of MAINTA and IFS users in basic information section.

Assumption H1: There is a significant difference between viewpoint of MAINTA and IFS users in basic information section.

$H_0: \rho = 0$

$H_1: \rho \neq 0$

For proofing the above assumption, it can use the independent parametric T-test. Table 7 addressed the first assumption of research.

Table 7. Evaluation of the first assumption

Statistical amount (t)	Degree of freedom (Df)	Punctual value (p-value)	The 95% Confidence level		Result
			Upper limit	Lower limit	
-0.148	26	0.884	3.44	-3.97	Assumption rejected

Considering the above mentioned punctual level (0.884) which is higher than 0.05, thus we conclude that there is not a significant difference between viewpoint of MAINTA and IFS users in basic information section. Thus, the first assumption of research is rejected and the H0 therefore is proved. However, respect to pervious tables that the mean scores for MAINTA software a little is bigger than the IFS score, thus it can be concluded that the MAINTA is seldom better than IFS software in Basic Information section, but there is not any significant difference between these two softwares from statistical point of view.

Table 8. Evaluation of the second assumption

Statistical amount (t)	Degree of freedom (Df)	Punctual value (p-value)	The 95% Confidence level		Result
			Upper limit	Lower limit	
1.182	26	0.248	6.51	-1.75	Assumption reject

3.2.2. The second assumption of research:

Assumption H0: There is not a significant difference between viewpoint of MAINTA and IFS users in planning section.
Assumption H1: There is a significant difference between viewpoint of MAINTA and IFS users in planning section.
H_0: $\rho = 0$
H_1: $\rho \neq 0$

For proofing the above assumption, it can use the independent parametric T-test. Table 8 addressed the second assumption of research.

Considering the above mentioned punctual level (0.244) which is higher than 0.05, thus we conclude that there is not a significant difference between viewpoint of MAINTA and IFS users in planning section. Thus the second assumption of research is rejected and the H0 assumption is then proved. But respect to pervious tables that shows the mean scores for IFS software is higher than the MAINTA, thus it can say that the IFS is much better than MAINTA software in planning section, but there is not any significant difference between these two software.

3.2.3. The third assumption:

Assumption H0: There is not a significant difference between viewpoint of MAINTA and IFS users in reporting section.
Assumption H1: There is a significant difference between viewpoint of MAINTA and IFS users in reporting section.
H_0: $\rho = 0$
H_1: $\rho \neq 0$

For proofing the above assumption, it can use the independent parametric T-test. Table 3.8 addressed the third assumption of research.

Considering the above mentioned punctual level (0.117) which is higher than 0.05, thus we conclude that there is not a significant difference between viewpoint of MAINTA and IFS users in reporting section. Thus the third assumption of research is rejected and the H0 assumption is proved. But respect to pervious tables that shown the mean scores for IFS software is higher than the MAINTA, thus it can say that the IFS is much better than MAINTA software in reporting section, but there is not any significant difference between these two software.

Table 9. Evaluation of the third assumption

Statistical amount (t)	Degree of freedom (Df)	Punctual value (p-value)	The 95% Confidence level		Result
			Upper limit	Lower limit	
1.62	26	0.177	6.14	-0.72	Assumption reject

3.2.4. The fourth assumption of research:

Assumption H0: There is not a significant difference between viewpoint of MAINTA and IFS users in other requirements section.
Assumption H1: There is a significant difference between viewpoint of MAINTA and IFS users in other requirements section.
H_0:$\rho = 0$
H_1:$\rho \neq 0$

For proofing the above assumption, it can use the independent parametric T-test. Table 10 addressed the second assumption of research.

Considering the above mentioned punctual level (0.161) which is higher than 0.05, thus we conclude that there is not a significant difference between viewpoint of MAINTA and IFS users in other requirements section. Thus the fourth assumption of research is rejected and the H0 assumption is proved But respect to pervious tables that shown the mean scores for IFS software is higher than for MAINTA, thus it can say that the IFS is much better than MAINTA software in other requirements section, but there is not any significant difference between these two software.

Table 10. Evaluation of the fourth assumption

Statistical amount (t)	Degree of freedom (Df)	Punctual value (p-value)	The 95% Confidence level		Result
			Upper limit	Lower limit	
-1.44	26	0.161	0.95	-5.46	Assumption reject

3.2.5. The fifth assumption of research:

Assumption H0: There is not a significant difference between viewpoint of MAINTA and IFS users totally.
Assumption H1: There is a significant difference between viewpoint of MAINTA and IFS users totally.
H_0:$\rho = 0$
H_1:$\rho \neq 0$

For proofing the above assumption, it can use the independent parametric T-test. Table 11 addressed the fifth assumption descriptive statisticians of research.

Table 11. Descriptive report for research assumption

Groups	Mean	Standard deviation	Standard devition error
IFS	50.4	14.73	4.66
MAINTA	47.83	1389	3.27

Table 12. Evaluation the fifth assumption proof of research

Statistical amount (t)	Degree of freedom (Df)	Punctual value (p-value)	The 95% Confidence level		Result
			Upper limit	Lower limit	
0.459	26	0.650	14.07	-8.93	Assumption reject

Based on above table it can conclude that the mean scores that respondents assigned to IFS software is higher than MAINTA.

Considering the above mentioned punctual level (0.650) which is higher than 0.05, thus we conclude that there is not a significant difference between viewpoint of MAINTA and IFS users totally. Thus the fifth assumption of research is rejected and the H0 assumption is proved. But respect to table 11 that shown the mean scores for IFS software is higher than for MAINTA, thus it can say that the IFS totally is much better than MAINTA software, but there is not any significant difference between these two software. Of course there is a significant difference between them in financial viewpoint.

In one of tenders it was seen that the final cost related to IFS software is much higher than MAINTA which detail information is provided in Table 13.

4. Conclusion and further recommendation

Based on an investigation conducted in 2000 and 2004, the consistency of software is the most important reason for companies through software selection process. However, costs of implementation, maintenance and updating (typically between 17 to 22 percent of total cost for purchasing the license) are belonging to costs that a buyer should pay since the CMMS softwares lost their efficiency if they don't update periodically. On the other hand, most of software developers don't allow users to change the software settings and this only allowed with paying an additional cost. Respect to importance of installation and implementation of CMMS software and similarity of most softwares in efficiency viewpoint, for each case, the software should be evaluated both technically and financially through a significant statistical analysis. Finally the overall score should be considered for making the final decision. It normally varies from a company / project to the others due to attribute required for implementation. The results of this study indicates the two software were the same from technically point of view which confirmed by hypothesis testing. Therefore the cheaper one was selected. Further research can be conducted for the other cases in various companies since the results of this research was adapted on a field study and this does not necessarily means the obtained results of this study can be applied through all cases. Therefore, for different cases, fields study using statistical analysis to be separately implemented.

Table 13. The costs related to the two software

Item	IFS proposal	APAVE proposal
Onshore (45 users)+ offshore (30 users)	CMMS and EDMS (Euros)	CMMS and EDMS (Euros) + CERDO (Euros)
Software license	Higher price	-
Implementation (installation, configuration, initial customization)	Higher price	-
Training	Higher price	-
Annual maintenance (hot-line+ new version)	Higher price	-
Total	Higher price	-

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