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Artículo Original

A new approach for strategic maintenance management based on soft-computing generics algorithms

Un nuevo enfoque para la gestión del mantenimiento estratégico basado en algoritmos genéricos informatizados

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Abstract

The objective of this research was to provide soft-computing generics algorithms to manage the primary actions of the maintenance function, through the integration of tangible and intangible assets of a company. The design methodology used is based on the RUP (Rational Unified Process). The implementation was made with the C++ Builder compiler and was used PostgreSQL as database manager. Among the main results obtained are an increased the quality of the process since 100 % of the data collected in the work orders is tabulated in the database, reducing considerably the time of searching information related to work orders issued. It also was achieved a reduction of 13,994.03 hours per year, which translates as an increase in the equipment availability indicator.

Key words: generics algorithms, soft computing, strategic maintenance, assets management.

Resumen

El objetivo de esta investigación fue proporcionar unos algoritmos genéricos informatizados para gestionar las acciones primarias de la función mantenimiento, a través de la integración de los activos tangibles e intangibles de una empresa. La metodología de diseño utilizada se basó en la RUP (Proceso Unificado Racional). La implementación se realizó con el compilador C ++ Builder y se utilizó PostgreSQL como gestor de bases de datos. Para evaluar la efectividad de los algoritmos se analizó un intervalo de tres años antes y tres años después de su implementación. Entre los principales resultados obtenidos se encuentra un incremento de la calidad del proceso, pues el 100 % de la información de los datos recogidos en las órdenes de trabajo se encuentra en una base de datos; reduciendo considerablemente el tiempo de búsqueda de información relativa a las órdenes de trabajo emitidas. Adicionalmente se logró una reducción de 13954,03 horas anuales, destinadas a acciones preventivas o correctivas, lo que se traduce en un aumento en el indicador de disponibilidad de los activos.

Palabras claves: algoritmos genéricos, informática básica, mantenimiento estratégico, gestión de activos.

Introduction

Business management refers to the administration of a company; it is related to the disaggregations: planning, direction, coordination and control; which have been abruptly synthesized by modern approaches to business management. At the beginning of the 21st century, advanced companies began to apply the integral asset management process, taking into account that the assets are the primary source of wealth production in a company [1, 2]. These companies operate as an integrated process, which interrelate the traditional functions (operations, asset maintenance, purchasing, finance, risks, environment, human resources, distribution, marketing and technology). Nevertheless, in order to the intangible resources generate value for companies, it is necessary to manage them according to management models witch are sometimes sophisticated, complex and practically lack empirical evidence [3].

Simões, Gomes and Yasin show that an effective assets management from a strategic point of view, have direct implications for organizations that try to measure the effectiveness of their maintenance efforts [4]. On the other hand, Fraser in a study carried out in 2015 on maintenance management models, highlights the importance of finding a practical approach in modern strategies for managing the maintenance function [5].

Maintenance department is the principal responsible of keeping the company assets at the most highest level of availability, through preventive maintenance programs and the control of corrective actions. To reach the operational excellence and reduce the losses that appear throughout the operation chain and, at the same time, improve the management capacity of all the personnel involved in the production; the complete integration of the entire team should be sought. To face this challenge, new methods or management models applicable to these environments have been developed, such as Reliability-centered maintenance (RCM), Risk-based maintenance (RBM), Condition-based maintenance (CBM), Availability-based maintenance (ABM), and Evidence-based asset management (EBAM), Prognosis Help Management (PHM), among others.

These advanced techniques require, in most cases, informatics management systems or informatics tools; which can be very complex if they lack computer tools for their control [6-8]. The implementation of computerized systems with the aim of managing the company assets, is considered a good maintenance practice to achieve excellence. Despite this reality, success depends on the adequacy of the computer system with the functional requirements of the company [9]. Many benefits can be obtained by applying asset management strategies based on computer applications [10, 11].

Wienker, Henderson and Volkerts, developed a study that allowed identifying the impact of computerized systems for maintenance management on the overall results of the company. In some cases the results were negative and were attributed, among others, to the low level of training of technicians in these environments and the lack of support by the top management of the company [12]. Fumagalli, considers that before implementing a modern strategies for maintenance management, it is necessary to have a computer application or computer processing algorithms well-structured that allow the treatment of data [13]. Other authors consider that the strategic assets management, through computer applications, is expandable to any environment, including the hospital and biotechnology sector. Regardless the level of complexity of these scenarios, could be reach benefits such as the provision of a better health service and the extension of the useful life of medical assets [14].

Many companies lack the possibilities or resources to acquire and implement a computer platform to manage its assets. Not with standing, it is possible to achieve good results by applying techniques, methodologies, routines or adequate procedures to manage the primary actions of the maintenance function (prevention and correction). The goal of this research is to provide soft-computing generics algorithms to manage the primary actions of the maintenance function, through the integration of tangible and intangible assets of a company. Preventive maintenance planning and the control of corrective actions must be included in the basic functionalities of any computerized maintenance management system.

Method

The design methodology used is based on the RUP (Rational Unified Process). RUP is a software development process created by the company Rational Software Corporation, now owned by IBM. Together with the Unified Modeling Language (UML), are the general-purpose, developmental, modeling language in the field of software engineering, that are intended to provide a standard way to visualize the design of a system, guided by Use Cases (UC). RUP is not a single concrete prescriptive process, but rather an adaptable process framework, intended to be tailored by the development organizations and software project teams that will select the elements of the process that are appropriate for their needs [15, 16].

The implementation was done with the C ++ Builder compiler and was used PostgreSQL as database manager [17, 18]. The algorithms designed were used to update the version of the GEMA 2.0 system, designed to computerize the maintenance function in a hospital environment or biopharmaceutical production company [19].

Procedure

To design the algorithms were taken into account a series of requirements or elementary conditions, which allowed standardizing the flow of information in the maintenance department. This technique is known as business rules, and for the case under analysis are defined below.

- The technical service request (TSR) is the only way to attend the technical service needs, between the maintenance department and the other departments of the company.
- Maintenance specialists are the only responsible to process technical service request. It is the main source to quantify indicator response to a technical service request (RTSR).
- The information management in the maintenance department will be done through a work order (WO).
- Work order (WO) will be the primary data collection document in the maintenance department. It is the main source to quantify the mean time to repair (MTTR), mean time to failure (MTTF) and mean time between failures (MTBF) indicators.
- A work order will be assigned to a technician, but more than one can participate on it, and even the original technician can be changed.
- In the confection of the plan of preventive maintenance will be determined the frequency with which the maintenance will be applied (Evidence-based asset management) and the type of intervention associated with each asset (Condition-based maintenance).
- Planned preventive maintenance will be applied to the maintenance technical inventory (TMI) assets. TMI includes only those assets served by the company's technicians.
- Corrective maintenance will be applied to the maintenance general inventory (GMI) assets. GIM includes whole company's assets even those on maintenance technical inventory.

Results

The results shown in figures 1 and 2 are related to the business objects that are involved in the proposed algorithms. Moreover reflects the implementation model of the proposed algorithms and its connection to the GEMA computer system. figures shows the business logic, the data access mechanism and its interaction with the computer system.

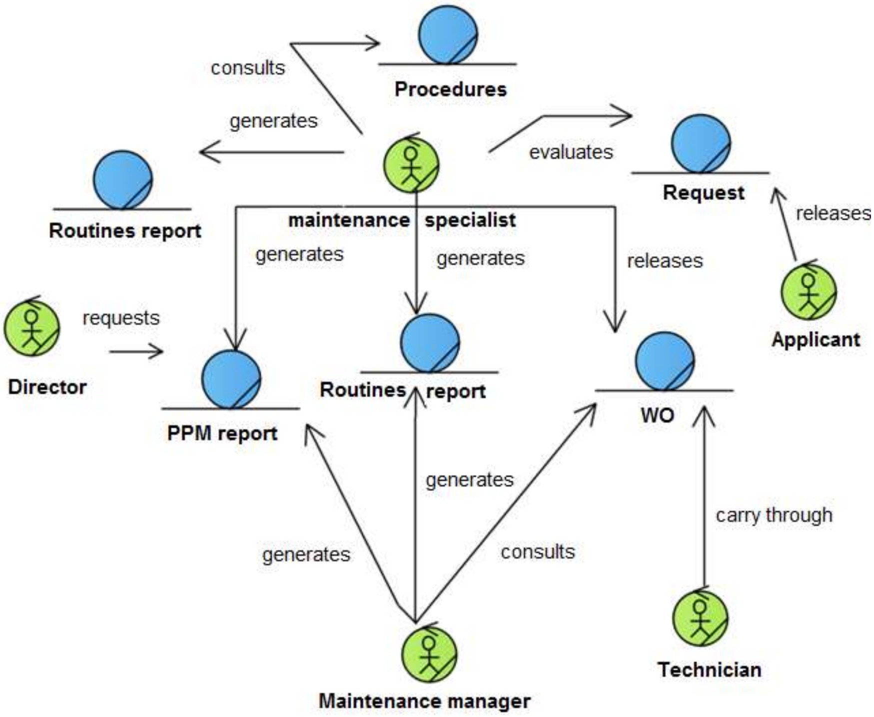

Fig. 1. Business objects diagram

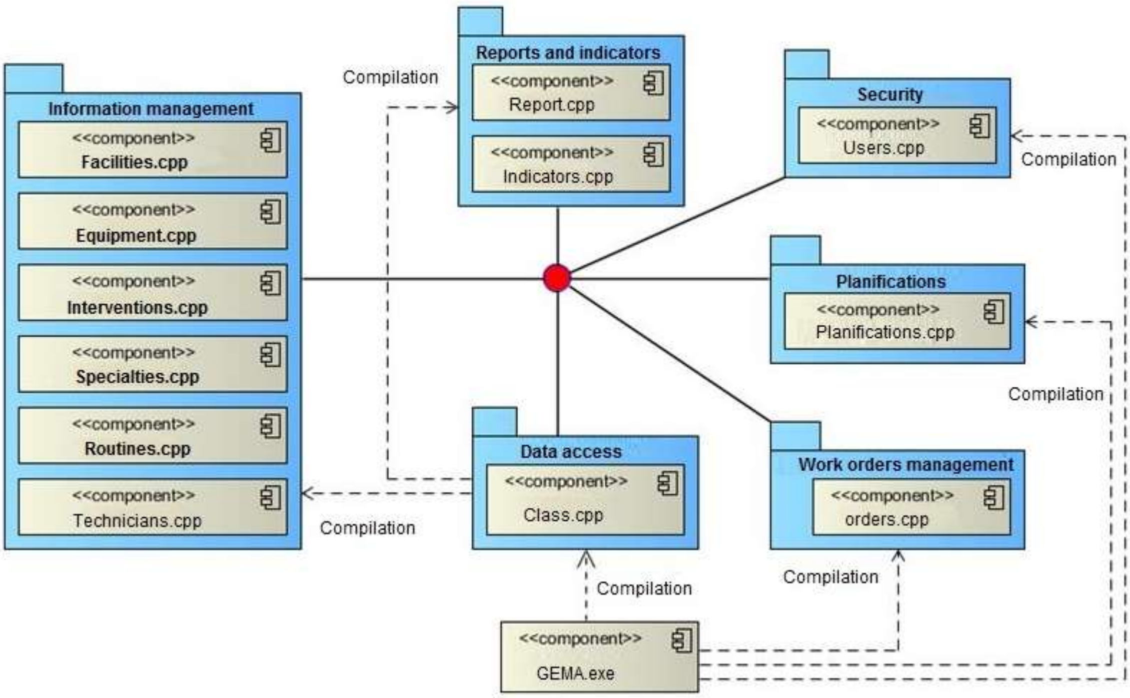

Fig. 2. Implementation model

Figure 3 shows the algorithm corresponding to the use case (UC): manage corrective maintenance

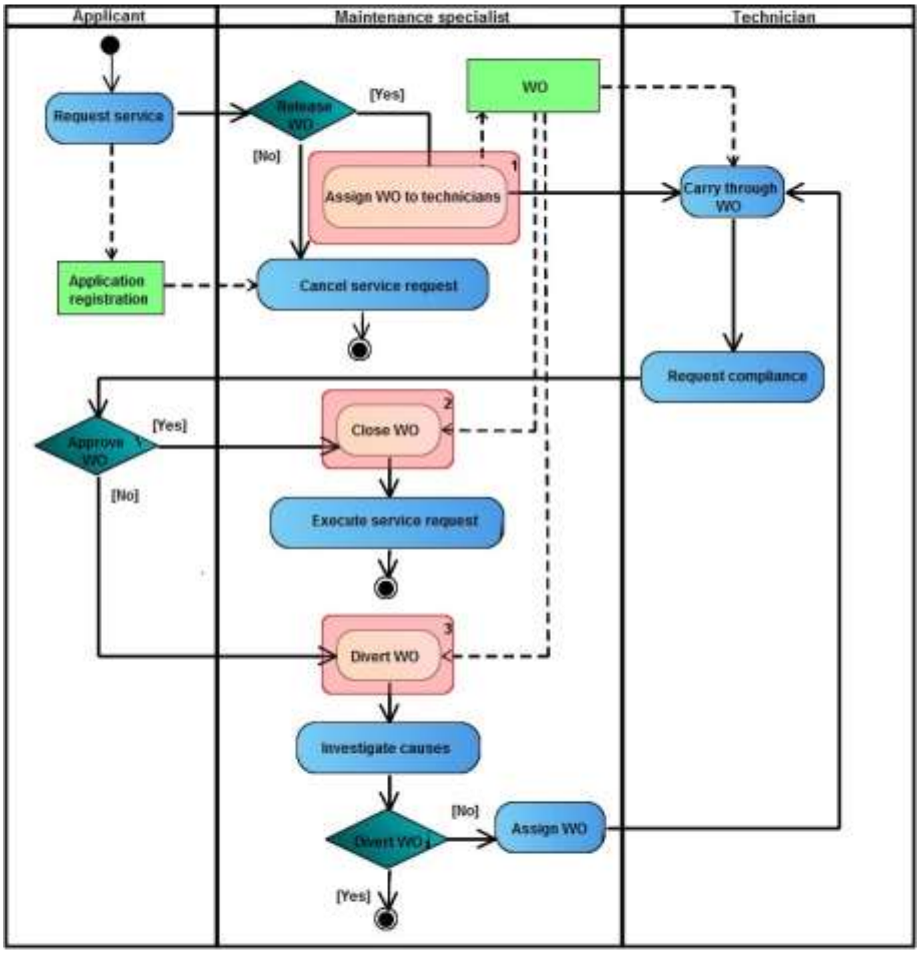

Fig. 3. Generic algorithm to manage corrective maintenance

Figure 4 shows the algorithm corresponding to the use case (UC): plan preventive maintenance

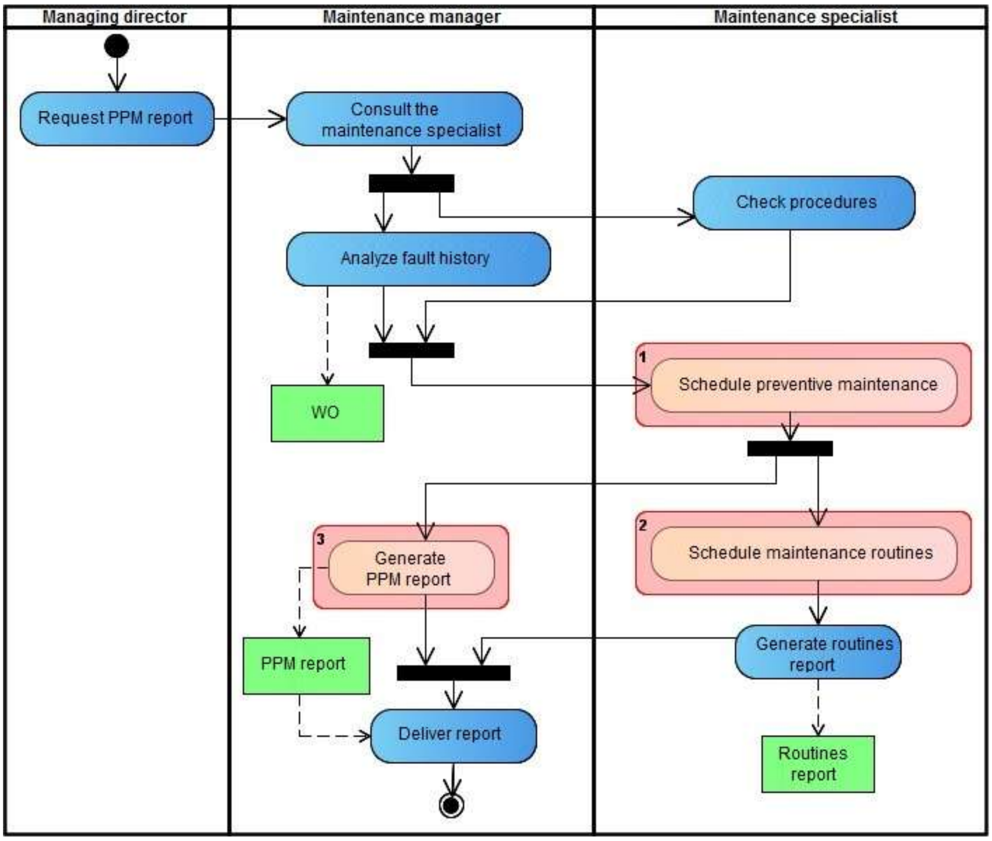

Fig. 4. Generic algorithm to manage preventive maintenance

Discussion

The algorithms proposed include new features to be implemented in the GEMA computer application. Figure 1 and Figure 2 show the system actors that intervene in the use cases under analysis and their interconnection with the existing computer application. These actors will play leading roles in the preventive maintenance planning and the corrective actions control. Following it is define the access privileges in correspondence with the roles they play as business workers.

- **Maintenance Manager:** is responsible to control all the activities of the maintenance department. Has a direct participation in whole processes.
- **Maintenance Specialist:** is responsible to control the activities of the maintenance department according to their specialty. Subordinate directly to the maintenance manager.
- **Technical:** perform corrective and preventive actions to respond a technical service request concerning his specialty. Subordinate directly to the maintenance specialist.
- **Applicant:** any worker in the company that requests an intervention of technical services to the maintenance department.
- **Director:** maximum responsible of the company.

Once the roles of the actors in the system have been defined, the next step in the process is to carrie out an analysis detailed of the soft-computing generics algorithms proposed. The use case model allows developers and clients to reach an agreement about the conditions and possibilities that the computer system must fulfill and offer. In this way, each algorithm will form a generic use case in the system.

Use case: manage corrective maintenance

When a fault occurs or it is necessary to perform another kind of intervention, the worker in charge of the area or the asset where the work must be performed (applicant), registers his technical service request; through the GEMA computer application. Next, one of the maintenance specialists analyzes the technical service request and decide to issue or not a work order. This is a key aspect in the process. Traditionally, is it assign erroneously the responsibility of issuing a work order to the department secretaries.

For many reasons a maintenance specialist decides does no issue a work order, for example, a wrong requests due to ignorance in the operation of the technology (4 % of requests per year), equipment not energized (3 % of requests in a year), among other [9]. It is important to bear in mind that indicators like RTSR, MTTR, MTTF, among others, depend on the data that is collected in a work order or technical service request. Issuing work orders in the aforementioned cases, mask the real values of these quality indices. On the other hand, it is decide to issue one or more work orders is assign the responsibility of executing it to a technician. This is one of the functionalities that must be registered in the software GEMA (UC: Assign WO).

Once the work is finished, the applicant evaluate the conformity with the work executed. If the process is satisfactory, the technician delivers the WO to the corresponding specialist to evaluate the costs and complete the process (UC: Close WO), the client's request being resolved. If there is no agreement with the work executed, the WO is declared as deviated (UC: Deviate WO) and begin a process of analysis to determine the causes of the non-conformity and assess the final status of the WO.

Alternate flows analysis

Maintenance specialist could not issue a WO for the technical service request. In this case, the technical service request is canceled (UC: Cancel WO) and the use case ends.

If there is no agreement with the work executed, the maintenance specialist proceeds to:

- Declare the work order as deviated.
- Investigate the cause of the deviation.
- Depending on the investigation result, the maintenance specialist can decide re-executed the work order or declared it as definitively deviated (document non-compliance with the quality assurance department). The use case ends.
- If it is feasible to re-execute the work order, the maintenance specialist will assign the work order to the indicated technician, who will request the conformity with the work performed one more time.

Finally, the shaded and numbered activities 1, 2 and 3 were reprogrammed in the GEMA computer application. This action increased the quality of the process since 100 % of the data collected in the work orders is tabulated in the database, reducing considerably the time of searching information related to work orders issued.

Use case: plan preventive maintenance

The interventions and changes of some components or parts to the assets, are programmed based on an analysis of the frequencies, the nature of interventions recommended by the manufacturer or maintenance specialists and break history of each asset. In other words, this is the Evidence-based asset management model. The necessary data for the analysis are obtained by consulting the work orders in the GAME computer application. Parallel to planning preventive maintenance, it is carried out planning maintenance routines. Its purpose is to offer a series of steps (standard) attached to the work order to guide maintenance technicians in the execution of planned preventive maintenance In other words; it is the beginning of Condition-based maintenance model. The maintenance manager and the maintenance specialists carry out planning preventive maintenance and planning maintenance routines. At beginning of each year the director of the company demand the maintenance manager for a report with the planning of preventive maintenance, taking into account the strategic management model adopted by the maintenance department (it is the responsibility of the entire company to optimally operate their assets). Finally, the shaded and numbered activities 1, 2 and 3 were reprogrammed in the GEMA computer application. The execution time to develop these activities manually exceeded 40 working hours per week; however with the computerization of these processes is achieve a reduction in the order of minutes

From the incorporation of the algorithms developed in the GEMA computer application, an improvement in the planning and control of the preventive and corrective tasks of the company has been achieved. The following statement can be verified by means of the graphs of figure 5 and figure 6, where are proved the effectiveness of the algorithms developed three years before and three years after its implementation.

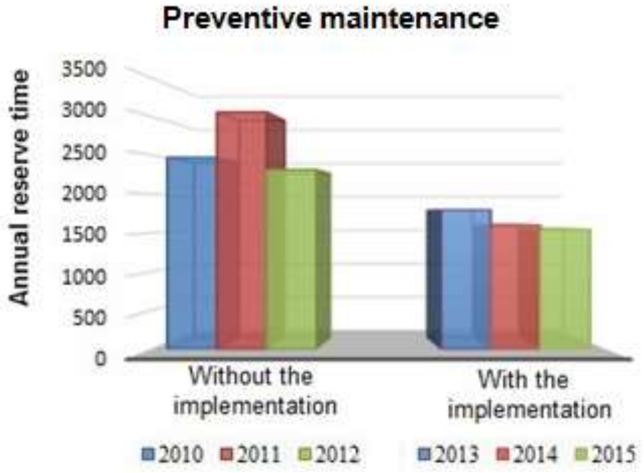

Fig. 5. Annual reserve time for planed preventive maintenance

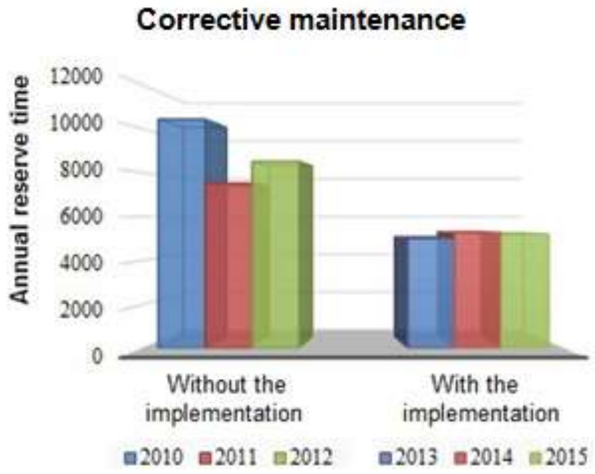

Fig. 6. Annual reserve time for corrective maintenance

It was used around 34,348.71 and 20,394.68 hours per year to perform preventive and corrective maintenance tasks in the period 2010-2012 and 2013-2015 respectively. With the incorporation of soft-computing generics algorithms, it was achieved a reduction of 13,994.03 hours per year, which translates as an increase in the equipment availability indicator.

Conclusions

Managing properly the company assets presuppose a high performance in its functions. Through the combination of modern techniques for asset management, it is possible design procedures, methodologies, algorithms, etc., that allow a control of the primary actions of the maintaining function (prevention and correction). The key to success lies in the integration of all the factors in the company, through the integral management assets. Is possible to observe through the results reached the good performance of the strategic management adopted by the company for the assets maintenance management. The results show among other, a reduction of 13,994.03 hours per year, which translates as an increase in the equipment availability indicator

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