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Developing a Model of Equipment Maintenance and Repair Process at Service Repair Company Using Agent-Based Approach

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Abstract

In this paper we examine development a model of equipment maintenance and repair process at service repair company using agent-based approach for increase of efficiency of use the available funds for maintenance and repair of equipment, reduce the load on specialists. We have analyzed the MRO process of repair-service facility. The basic objects of the model and the functions they perform are defined in this paper. We use agent-based approach to simulate the MRO process. The conceptual and logical models of MAS of the MRO process have been developed.

Keywords: equipment; maintenance; repair; maintenance and repair; maintenance and repair organization (MRO); MRO process; service repair company; software support of maintenance and repair; agent-based modeling; multi-agent systems; intelligent agents; agent-based approach; automation; simulation model.

1. Introduction

Nowadays the dominant goal of economic policy in both developed and developing countries is the growth of the national competitiveness and increasing the share of domestic companies in the domestic and international markets, as well as improving the efficiency of their operations.

The processes of globalization and the increasing international competition, which characterize the global economy, were objective prerequisite paradigm shift management of competitiveness, which is the rejection of traditional industrial policy and the transition to the new system of organization of production, which is based on the benefits of

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specialization and cooperation. In order to modernize the industry and ensure its competitiveness there is a need of serious investment injections [1].

The main objective of improving the quality of operation of the equipment is to ensure a long and trouble-free processing of the parts with specified performance, accuracy as well as with minimal time, labor and money on maintenance and repair organization (MRO), which are necessary to restore the technical qualities of machines which is lost during the process of operation. To solve this problem facility organizes system of maintenance and repair (M&R) process of tech equipment.

Management system of M&R process of tech equipment carried with impact on MRO regime characterized by periodic maintenance and maximum admissible (critical) deviation of diagnostic parameter, (criterion of limiting state) equipment from the normative values. Consequence of the effective implementation of this intervention is to improve the content of the existing equipment and a clear realization of all kinds of its systematic maintenance and planned repairs. It increases the adaptability of operating period of the life cycle of machines, in other words maintainability, which should be used as a criterion of effectiveness of MRO process [2].

2. Agent approach

The task of preventing failures of dynamic equipment is largely connected with the problem of forecasting its technical state. Dynamic technical condition is defined by factors which determine the course of the degradation processes in the dynamic elements of the equipment. Under degradation processes we understand mechanic-physical-chemical processes occurring in the material details, causes changes in the technical state of the following elements of the hierarchy "detail - subassembly - mechanical system" and leading to the cessation of operation and / or compromises operation [3, 4].

Using of modern technologies of simulation is one of the effective ways of finding a decision to the problem of forecasting and examining of technical condition of dynamic equipment. Since dynamic equipment is an object with a complex structure and its state consists of states of all its elements it's advisable to use the Agent-based approach in order to model its technical condition.

This approach allows us to simulate the behavior of complex-structured objects and it serves to simulate systems which consist of a large number of subsystems each of them has an individual behavior. [5, 6].

A very important advantage of agent-based modelling is that there is no need to detail the behavior of the system as a whole, it is possible to develop a model in the absence of in-depth knowledge of global dependencies, and it makes a great difference to the system dynamics models or discrete models. We can construct agent-based model basing on the knowledge of the individual logic behaviour of its objects. Information about the features of the dynamics of the whole system can be derived from the results of studies of the models behavior. Agent-based model is easier to maintain: refinement is usually made at the local level and do not require global changes [7, 8]. It is obvious that the application of this modelling approach is most convenient when we are interested in the behavioral characteristics of the entire system, which are defined as the integral characteristics of the entire set of agents. Depending on the intended purpose, one and the same system can be constructed in simulation under various paradigms.

Thus, now is the actual task of optimizing the system control maintenance and repair of process equipment engineering facilities by maintainability impact on MRO regime based on the implementation of the principles of the process approach [9].

Current scientific developments in this field have been reviewed such as:

- The development of a simulation model predicting the dynamic changes of the status of technical systems for effective planning of a cost for maintenance and repair [10].
- Creating simulation simulation of the MRO process models based on intelligent agents [11].
- Development of systems to support MRO process decision-making [12, 13].
- Integrated approach study process of repair and maintenance of the equipment of the facilities [14].
- Modelling of MRO process in different areas such as aviation and astronautics, oil refining, machine building, metal-working, and etc. [15, 16].

3. Goals

The goal of this work is to improve the efficiency of the use of available funds for the maintenance and repair of equipment, reducing the load on the experts, as well as development of software that would allow simulating the MRO process of a facility.

To achieve this goal we have defined following tasks:

1. Domain Study – the industrial equipment maintenance and repair process in order to determine process steps and critically significant ones;
2. Developing the MRO facility model;
3. Development of conceptual and logical models of MAS of the equipment MRO process.
4. Development of software tools to implement the prototype of MAS, which models the MRO process and give the simulating tool to obtain a clear picture of the equipment MRO process.

4. MRO process analysis

During the work, the business-process of MRO of a repair-service facility has been researched and analyzed – the results are presented graphically on the Fig №1.

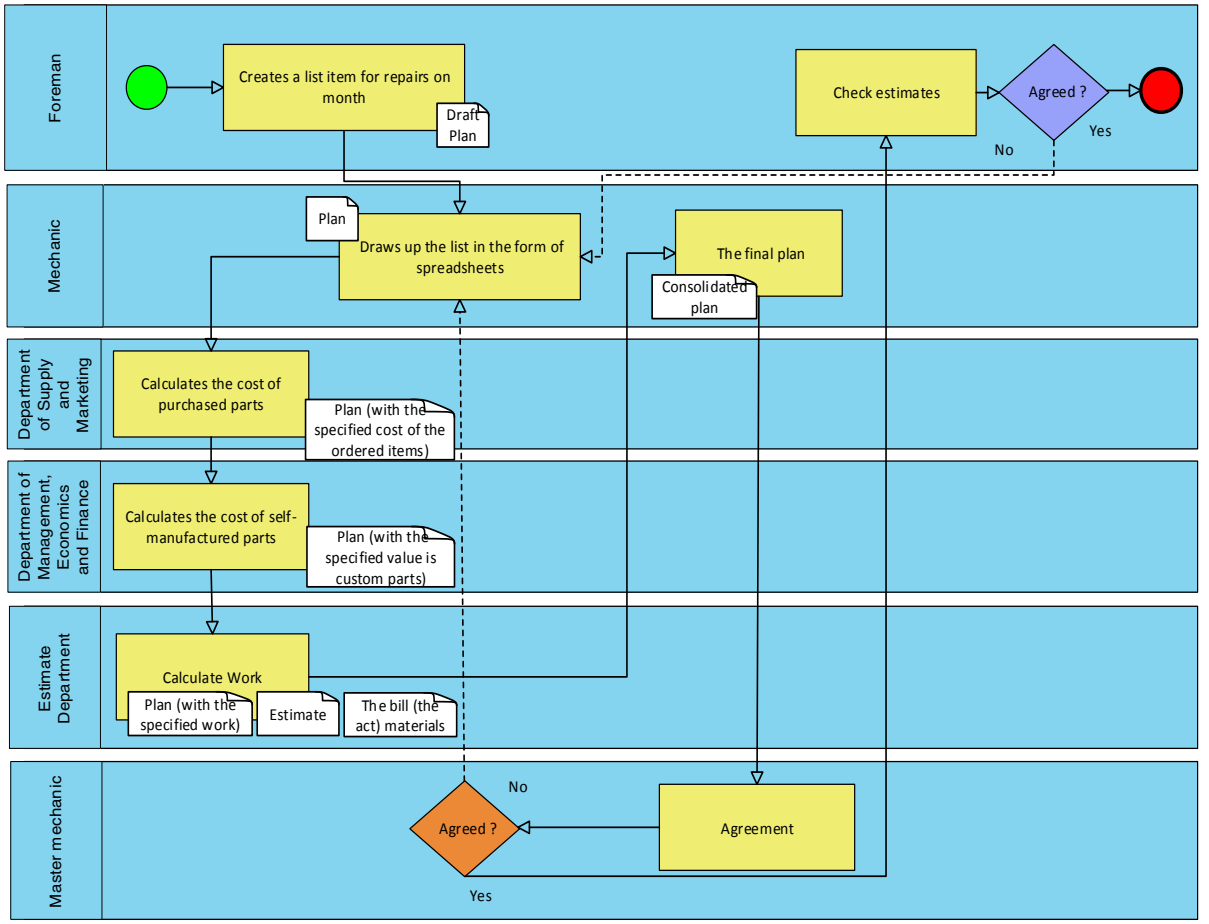

Fig. 1. The main fragment of the studied business process of MRO schema

The object of the research is the process of inspection and repair. In order to research and to model this process we have selected a repair and service company, which performs maintenance and repair of different equipment for various customers in many geographically dispersed locations.

The subject of our research is the process of repair and maintenance of the repair-service facility, to be more exact it is the way a repair team, which is specialized in one type of the equipment, performs this process. For example, dynamic equipment: pumps. A repair team works by the repair technology according to a factual condition of equipment.

Repair team performs the following tasks:

- periodic inspection of the equipment;
- apply for a parts from store;
- repair of the equipment;
- equipment start \ stop;

During MRO, repair team can identify the following periods:

- inspections of equipment;
- deciding if a repair is necessary;
- stop the equipment;
- filling and submitting an application for the necessary parts at the store;
- sending a request for missing parts in stock to the supplier;
- obtaining details from the supplier;
- storing parts and giving it to a master;
- obtaining of a set of parts and repairing equipment;
- start to running of equipment.

The main essence of the process MRO was highlighted:

1. Equipment is technological object, which is loaded with materials or blank means, and technological snap to perform a specific part of the process. These include, for example, casting machines, presses, machine tools, test equipment, etc.
2. Master is a skilled worker engaged in inspection, technical maintenance and repair of equipmentt;
3. Warehouse is a space (or a complex of it) for storing the material values and the provision of storage services. In logistics warehouse performs the function of accumulation of reserves of material resources, needed for vibration in the supply and demand, as well as for syncing speed of the flow of goods in the transportation systems from the manufacturers to consumers or material flows in industrial production systems.
4. Supplier is any legal entity (organization, company, institution) or a natural person who is supplying goods to customers. Supplier carries out business activities in accordance with the terms of a contract, which is a type of a sale contract. In the supply contract, the Contractor shall transmit goods produced or purchased by him to the due date or dates to the buyer for use in entrepreneurial activities or other purposes not related to personal, family, household, or other similar use.

5. Developed model description

During a detailed analysis of the MRO process of the repair-service company we have defined the main objects of the model and sets of functions which they perform.

Table 1 Basic objects and functions of the model

Object	Functions
Equipment	The operability status.
Mechanic	Equipment inspection; Equipment stoppage; Parts Ordering; Details acquisition; Equipment launch.
Warehouse	Receiving the order; Order fulfillment; Details acquisition; Parts Ordering; Items reception.
Supplier	Receiving the order; Order fulfillment; Details acquisition;

The model of the multi-agent system is developed on a base of a detailed analysis. We have added one more object "Chief Engineer" who supervises the work of all objects "Engineer". He takes repair requests from them and distributes work according to a current workload.

Agents «Agent» in the model are set out : the identifier ID (name of agent), O - multiple agents that are associated with this agent , the repetition frequency of action the owner's agent with other agents, Freq, and a plurality of basic organizational structures - ORGA, relevant specific functions (roles) agent:

$$Agent = \{ID, O, Freq, ORG^A\} \quad (1)$$

The organizational structure of the agent is formally described as:

$$ORG^A = <S^A, R^A, CP^A, ACT^A, Rem^A, STR^A, L, ST, SL, T> \quad (2)$$

Where:

- S^A - Agent's goals set that it has to perform to complete for its task ;
- R^A- agent roles set which he must act to achieve the relevant objectives;
- CP^A - the agent skills and abilities set, which he must possess to give to fulfill the respective roles;
- ACT^A- set of the agent's actions;
- Rem^A – Agent's memory that stores the actions performed by the agent;
- STR^A- agent's behavior strategies set which leads towards achieving the relevant objectives;
- ST - set of states of the agent;
- SL – agent's operation limitations set.
- T - generalized transition function
- T: ST × ACT × SL → 2ST , satisfies the following conditions:
  a) for any st ∈ ST, act ∈ ACT, sl ∈ SL, if the state st satisfies restriction of φ, st |= φ, and a pair of <act, φ>∈ sl, then T<st, act, sl> -> φ;
  б) for any st ∈ ST, act ∈ ACT, sl1, sl2 ∈ SL, если sl1 > sl2 , то T<st, act, sl1>″ T<st, act, sl2>.

Agent memory - preserving processes executed by the agent is represented as:

$$Rem^A = Save\ (st_0 - (act^{0/}/sl_0)fi\ st_1 - (act_1/sl_1)\ fi\ ...st_n - (act_n/sl_n/)fi\ ...) \quad (3)$$

The repetition rate of the owner's agent actions with other agents is presented as a function depending on the interacting Ce, certificate, the relationship between them and the history of the agent Rem^A:

$$Freq = f(Agent, O, Rem^A) \quad (4)$$

Where the f () function is a processing of repetition frequency of interacting actions and descending sorting of O familiar sets of agents'.

Agent "Equipment" has the following states:

- work;
- idle;
- breakdown.

It also includes a list of parts and relationships that make up the equipment. Several key parameters for each element by which the values of the state of the equipment are determined.

Agent "Mechanic" has the following states:

- diagnostic an equipment;
- launching an equipment;
- repair of an equipment;
- stoppage of an equipment;
- sending an equipment state data to "Master mechanic" agent;
- receiving instructions from agent "Master mechanic ";
- obtaining materials for the repair of the agent "Master mechanic".

Agent "Master mechanic" has the following states:

- receiving a report on the state of the equipment from the agent "Mechanic";
- analysis of the resulting report;
- deciding on a repair necessity;
- ordering the necessary parts for repair;
- obtaining the necessary parts for repair;
- transfer advice and parts needed for repair to agent "Mechanic";
- load distribution between the agents "Mechanic".

For a decision on the need to repair agent "Master mechanic" uses the knowledge base. Now there is still no generally accepted methodology and universal MRO. Therefore, different methodologies for modeling process MRO must use the knowledge base, designed specifically for the chosen methodology. It makes this process a bit more complicated.

"Supply" agent has the following states:

- receive a list of items from the agent "Master mechanic";
- order parts from the supplier;
- receipt of the items from the supplier;
- transmission parts agent "Master mechanic";
- search and order these parts.

In the absence of the necessary parts, agent "supply" can search similar items with the use of a knowledge base on the coincidence of structural parameters and function.

To search for similar items developed knowledge base based on AND/OR graph. The AND/OR graph consists of the following elements:

- Repair subject. It is equipment. It contains functions.
- Functions. This is actions that can be performed to repair or nodes. It contains links and details.
- Node. It is element of equipment that can perform a set of functions separately from the hardware. It contains functions.
- Detail. It is an element which doesn't have any functional features.

The developed model is used to determine the amount of labor management technicians servicing company, by building models MRO process with different variations of congestion specialists. Data modeling of these processes is analyzed and these processes are compared to each other to determine the most optimal process of MRO with an approximately equal load on specialists. Just the proposed improvements on the supply stage can significantly speed up the search process and get the details now.

6. Conclusions & Implications

Simulation results of the developed multi-agent system can be used in the design and modernization phase to identify the suboptimal use of the specialists' time, justifying by uneven distribution of labor. During the operation phase model can be used to determine the residual life and to study the periodicity of maintenance and repair.

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