Field Service Management (FSM) Simulation Model

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Abstract: *This work is dedicated to the development of a simulation model of a Field Service Management (FSM) system. Its tasks include modelling the management of the activities of employees of a field service company: maintaining requests, dispatching orders and field workers, monitoring the quality of work performed. The goals of developing a model of a FSM are to increase the speed of customer service, ensure the process of quality control of work performed, reduce transport and time costs, and provide field workers with the necessary information to understand the scope and location of work. All this leads to improved quality of technical support and service and, as a result, customer satisfaction.*
Keywords*: FIELD SERVICE MANAGEMENT, FSM, AGENT, AGENT-BASED MODELING, MODEL, DISPATCHER*

1. Introduction

In a Field Service Management system, it is necessary to simultaneously coordinate many processes: processing flows of incoming and outgoing information, tracking and distributing service resources (Technicians) and technical equipment, managing employees who are on the road, monitoring the quality of the work they perform, etc. The proposed modeling technique allows us to take into account various qualitative characteristics of field agents and their collective behavior, while obtaining adequate assessments of the implementation of the assigned collective task. The basis of the modeling methodology is a multi-agent simulation system for field service, which takes into account the targeted group behavior of a team of agents.

Currently, the market for modern FSM systems is growing at a significant pace [1][2], but the following tasks have still not been fully implemented - programming the rational behavior of an individual service resource agent, decision-making by the agent based on a collective task, assessment by the agent of the results of completing the common and his own task.

The object of study is models of agents capable of functioning as part of a team. The key point is the interaction between group members, which creates a system of constant feedback, and the target function is the direction of behavior not of an individual, but of the entire group of agents within the framework of a common task.

The relevance of the problem under study is due to the following factors:

- Research shows that more than half of organizations use manual field service management;
- A significant number of enterprises plan to transfer part of their operations to vendors in the coming years;
- About half the time, field workers lack key resources and information;
- Most companies are not confident that they have the necessary skills to use the vast amount of available information to significant benefit.

There are more and more places in the world around us that require periodic maintenance or repair. These are ATMs, vending machines, coffee machines, climate systems, intercoms, gas, water and electricity meters, elevators, rental cars or scooters, or the already commonplace routers of the Internet provider in our housing. Organizations responsible for the operation of a wide variety of equipment are interested in its efficient maintenance in terms of speed of work completion, optimization of material and non-material costs. The final result of their work directly affects the loyalty of customers who provide direct or indirect revenue to the organization. Inconsistency between the quality of work and the current state of the market leads to customers refusing their services and deprives companies of a competitive advantage in terms of meeting customer needs and service level agreements (SLA). [3][4]

To solve operational problems and optimize internal processes, a FSM system is being developed based on a simulation model and its analysis, which allows organizing the interaction of the company's key roles with data describing the customer's problem and the step-by-step stages of its solution.

2. Product requirements

2.1. Current state analysis

Using the Business Process modeling technique, we will create a model of an existing Internet provider in terms of providing services to end users (customers) and the company's existing infrastructure, geographically distributed in different parts of the city.

The key roles are: Operator, Dispatcher, Technician and QA.

The first accepts requests for service from customers, assigns priority to the request and places it on the list of requests awaiting execution.

The dispatcher compares the data on available technicians and attaches a request to them in accordance with the technician's qualifications and the materials he has, after which he transfers the request to the technician for execution.

He also receives reports from the technician on completed service appointments (SA), closes work orders and prepares reports and invoices for payment by the customer for the service.

The technician receives the SA request, goes to the place where it will be performed and carries it out. After which he draws up a report on the work done and materials used, signs it with the customer of the service (if the order came from the customer, and not from the company itself) and sends it to the dispatcher.

The QA specialist analyzes information in service appointments, work orders and pictures after the job has been completed. Based on the enterprise approval rules, he makes a decision on accepting the work as high-quality, or creating a new service appointment for additional work.

There is also an auxiliary role of the administrator, who is responsible for filling databases with organizational data, for example, a list of customers, a list of service contracts, a list of employees, a list of territories with working hours, a list of mobile workers and their qualifications.

With the existing business process model, there are the following shortcomings that negatively affect the satisfaction of customers, employees and enterprise management:

- Inability to predict the cost of future work;
- It is difficult to divide the city geographically into parts to delimit the work of technicians;
- Large overhead and time costs for moving technicians to work sites. Often their movements around the city are not optimized, since the technician is not always sent to the nearest location;
- Inability to control the movement and current location of technicians;
- Inability to timely inform customers about a technician's visit to ensure access to customer equipment;
- The difficulty of accounting for materials available to technicians that may be needed when performing work;
- Inability to control the quality of work performed;
- There is no way to track the execution time of the service appointment;
- There is no option for reminders about excessive waiting times for technician visit.

2.2. Future state analysis

To eliminate existing shortcomings and ensure flexibility, a following list of functional requirements has been compiled:

- The ability of creating a preliminary calculation according to the terms of the work order;
- The ability of entering requests from third-party services;
- The ability of dividing the service territory into non-overlapping zones;
- The ability to visually display the schedule of the planned work of each technician up to the minute;
- The ability to assign technicians to zones to minimize movement around the city;
- The ability of displaying a map indicating the SA address;
- The ability of observing the current position of the technician on the map;
- The ability to inform the customer of the work order about the Technician arrival time;
- The ability to take into account the materials available to the Technician vehicle;
- The ability of tracking the materials consumed by the Technician during the work;
- The ability of taking pictures of the result of work and perform quality control procedure;
- The ability to track service appointments closed as a “temporary solution” with subsequent execution of the service appointment as a “permanent solution”;
- Track the time of an open work order;
- Track Service Level Agreement of an open work orders in accordance with the existing customer contract;

3. Creating a simulation model

For this work, agent-based modeling is used [5], which is often used for the needs of human resource management [6].

In the environment under consideration, independent agents have predetermined characteristics and rules. Based on this, each agent individually assesses the current situation and makes decisions. The decisions made influence and change the system as a whole.

Agents, which are real components of the system, make decisions in the context of certain conditions. In the simulation model, the behavior of agents is assessed over a certain period of time associated with the completion of a task or the transition of the system from one state to another. The purpose of the assessment is to predict the possible development of the system as a whole. The task of each agent is to perform the assigned work in a certain environment, taking into account the available abilities. It is the presence or absence of certain abilities that influences the choice and type of problem to be solved.

There are the key abilities necessary for agent of the model [7]:

- The ability to process information coming from other agents and transmit it;
- The ability to prioritize assigned tasks is used to analyze and prioritize incoming service requests. Applications can be either external, from consumers of services and affect only this consumer (local and limited impact), or internal, related to the repair, modernization and development of the existing infrastructure of the enterprise and affect many existing and potential consumers (global and long-term impact);
- Ability to work with others and evaluate their abilities;
- The ability to set goals that can be goals for other agents;
- The ability to achieve the expected result of the goal;
- The ability to make decisions based on available information. If it is impossible to make a decision, request additional clarification;

In Agent-Based Modeling we implement the idea that our system can be modeled using agents, an environment and a description of agent-agent and agent-environment interactions.

For the current purpose we used NetLogo software [8].

4. Analysis and system design

As part of the analysis and system design work, an analysis of the product requirements was carried out, on the basis of which the technical design of the developed system was made. For graphical presentation of diagrams, the Unified Modeling Language (UML) is used [9].

To visualize use cases, a use case diagram has been compiled. It reflects the relationships between actors and use cases, the main purpose of which is to describe functionality and behavior, allowing the customer, end user and developer to jointly discuss the designed or existing system.

Fig. 1 *Use Case diagram.*

An activity diagram was created to visualize the activity. An activity is a specification of executable behavior in the form of coordinated sequential and parallel execution of individual actions, interconnected by threads that go from one node to the inputs of another.

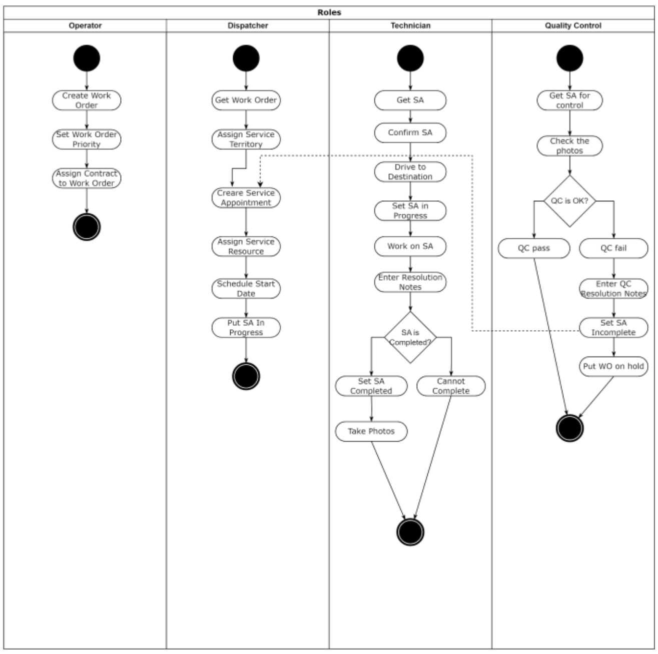

Fig.2 *Activity diagram.*

To visualize the life cycle of agents and the interaction of actors (roles), a sequence diagram was created. It allows us to show the multi-stage interaction of agents and their environment.

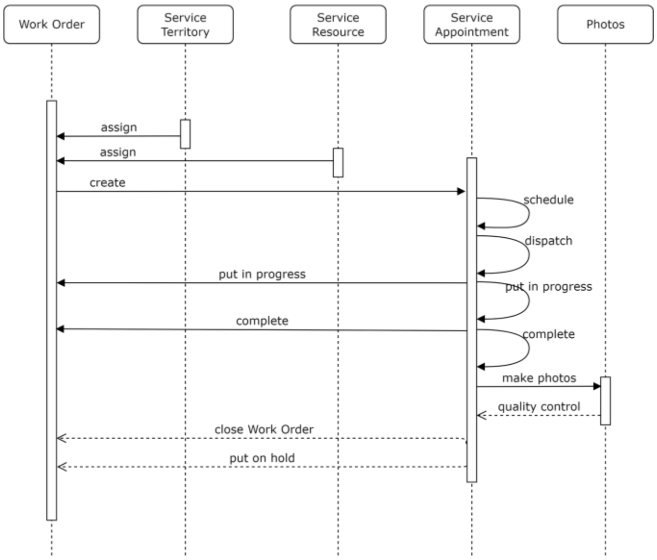

Fig.3 *Sequence diagram.*

In the process of creating the model, the following simulation model information blocks were identified:

Account is used to represent the entity of the customer to whom the company provides services and maintenance.
Main property:

- Name - to store the name of the customer.

Contract is used to represent an entity with information about contracts with customers.
Main properties:

- Name - for storing the name (number) of the contract;
- Account - identifier of the customer.
- Due Date—The expiration date of the service agreement.
- SLA Period - the service period (days) during which the work must be completed (after submitting a work order).

Work Order is used to represent an entity about work that needs to be done from the customer opinion or from internal company office.
Main properties:

- Number - to store the application number;
- Priority - to store the priority of the application. Possible values range from 1 (highest) to 4 (lowest);
- Contract - for storing the customer contract;
- Address - for address where service should be performed;
- Description - for information about what needs to be done in accordance with contract and the customer's complaint;
- Service Territory - to store a service area with Address;
- Status - to store the current status of the work order. The value is assigned automatically by the system depending on the actions of the Dispatcher or QA. Possible values:
  - New - the application has been created, no activity has been performed (default value);
  - In Progress - the work order has been accepted;
  - On Hold - the work order is suspended;
  - Completed - the work order has been completed;
  - Closed - all associated SAs have been completed;
  - Cannot Complete - the request can't be completed;
  - Cancelled - the application has been cancelled (Usually before any work on it begins).
- Created Date - to store the creation date. Set automatically by the system when creating an application; Used to inform the Dispatcher that the SLA has been exceeded according to the contract for non-finished work orders;
- Completed Date - to store the closing date. Set automatically by the system when the work order is closed. Used to assess the excess of the SLA for completed work orders.

Main actions:

- Change Status - a command to change the status in connection with an event that occurred (actions of the Dispatcher or Technician);
- Change Service Territory - a command to select/change the service area whose employees can perform work;
- Create Service Appointment - command to create a service appointment within the current service request.

Service Territory is used to represent the entity of the service areas, which may or may not be overlapping areas of the city.
Main properties:

- Name - to store the name of the service area;

Service Resource is used to represent the entity of field workers (Technicians) who can perform a specific type of jobs.
Main properties:

- Name - to store the ID of the Technician. May include abbreviations with his skills for easy identification.;
- Skills - to store skills for those jobs for which the Technician is qualified to perform.

Service Appointment (SA) is used to represent the entity of the work performed as part of work order. For one work order, there may be several service appointments for different Technicians, if the work cannot be done completely in one visit of specialists.
Main properties:

- Work Order – to relate the owner (work order);
- Scheduled Date/Time - to store a date when the SA is due;
- Duration - planned time to complete SA, min;
- Actual Start Date/Time - actual work start time (in fact);
- Actual End Date/Time - actual work end time (in fact);
- Status - to store the current status of the SA. The value is assigned automatically by the system depending on the actions of the Dispatcher and Technician. Possible values:
  - New - SA is not scheduled;
  - Scheduled - SA is scheduled. Assigned when the Scheduled Date/Time and Service Resource for a given request are assigned;
  - Accepted - Technician has read the service appointment details and is ready to start;
  - Dispatched - Technician is on the way for the work;
  - In Progress - Technician arrived and started work;
  - Cannot Complete - Technician does not have the opportunity to complete the work;
  - Completed - Technician has completed the work;
  - Incomplete - Technician did not complete the work; To complete, Dispatcher needs to create a new SA;
  - Cancelled - The work order has been cancelled. To resume work, Dispatcher needs to create a new SA.
- Resolution Notes - for completed work detains;
- QC passed - a flag about quality control successfully passed;
- QC Resolution Notes - for quality control notes by QA;

Main actions:

- Change Status - a command to change the status in connection with an event that occurred (actions of the Dispatcher or Technician);
- QC passed - a command to close a SA (and work order if there are no other open SA);
- QC failed - a command to close a SA and create a new one to repeat the work.

Photo is used to represent the entity of pictures after the Technician has completed the job and is reviewed by the QA team.
Main properties:

- Location - To store information about the location of a picture taken by a Technician.

Main action:

- Upload Photo - for automatically uploading images from Technician's mobile device camera and specifying the necessary information about the image in the object.
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5. Development of the dispatcher module algorithm

During the analysis of the dispatcher requirements, a number of criteria were collected that need to be implemented by creating a "Dispatcher Module":

- The module should display on the time scale the current disposition of service appointments with specified Scheduled Date/Time and Service Resource;
- The module should allow changing the Scheduled Date/Time by horizontally moving the graphic image of the service appointment;
- The module should allow you to change the assigned Service Resource by vertically moving the graphic image of the SA to the line with the another Service Resource;
- The module should do "auto-distribution" of service appointments: automatically set the Scheduled Date/Time and Service Resource for the new appointment, changing their status to "Scheduled". A special algorithm is used for this.

The following criteria are used to operate the algorithm:

- Priority - higher priority work orders are processed first;
- Geolocation - the location of the place of SA execution in relation to the place of execution of the previous SA is taken into account (to minimize travel time and distance);
- Service Territory - the territory to which the Technician belongs is taken into account. It is allowed to fulfil requests from another Service Territory if there is a significant difference in the workload of the Technicians. But working on "foreign" territory is not encouraged due to the delimitation of service areas and is considered high-cost for the purposes of the algorithm;
- Skills (Qualifications) - if SA contains information about the required skills of the technician, then the skills of the available Service Resource are taken into account when automatically distributing service appointments;
- Duration - the planned duration of the work is taken into account. Longer jobs are considered more expensive.

To develop a methodology for assessing the effectiveness of planning the Technician's working day, we will introduce the weight of each criterion:

Table 1. *Criteria and coefficients*

Criteria	Details	Criterion weight coefficient	Criterion conversion factor
Priority	Work Order priority (0..4)	p_1=80%	p_2=100
Geolocation (distance)	The distance from the previous SA location (or from the office for the first SA)	l_1=50%	l_2=3
Geolocation (travel time)	Travel time from the previous SA location (or from the office for the first SA)	t_1=70%	t_2=1
Service Territory	The flag to show if Technician is not assigned to the current Service Territory	s_1=80%	s_2=100
Duration	The estimated length of the service appointment	d_1=30%	d_2=1

Let us introduce the concept of the cost functional for moving to one object:

$$b = f(P, L, T, S, D),$$

where P - Priority of the service request;
L - distance to move from the previous object to the next, km. The system receives this data from the service [Google Matrix API];
T - time to move from the previous object to the next, min. The system receives this data from the service [Google Matrix API];
S - flag that shows that Technician is not assigned to the Service Territory of current Service Appointment, 0 or 1;
D - planned duration of work, min.

When estimating costs, we use criterion weight coefficients (p_1, l_1, t_1, s_1, d_1) to determine the weight of each criterion for reduction. We use criteria conversion factors to reduce criteria values to a common unit of measurement (p_2, l_2, t_2, s_2, d_2) according to table 1.

As a result, the costs of moving to an object in a chain of movements can be calculated using the formula

$$b = p_1*p_2*P + l_1*l_2*L + t_1*t_2*T + s_1*s_2*S + d_1*d_2*D.$$

For example, if there are different service appointments that differ only in priority and one more criterion (different ones), we have the value set:

Table 2 Test data

Priority and differences in Service Appointments	P	L	T	S	D	Sum, units	Delta, units	Delta, %
P1	1	5	30	0	30	120.5	0.0	0.0
P1, double distance	1	10	30	0	30	128.0	7.5	5.9
P1, double travel time	1	5	60	0	30	141.5	21.0	14.8
P1, alien Serv.Terr.	1	5	30	1	30	200.5	80.0	39.9
P1, more work time	1	5	30	0	50	128.5	8.0	6.2
P2	2	5	30	0	30	200.5	80.0	39.9
P2, double distance	2	10	30	0	30	208.0	87.5	42.1
P2, double travel time	2	5	60	0	30	221.5	101.0	45.6
P2, alien Serv.Terr.	2	5	30	1	30	280.5	160.0	57.0
P2, more work time	2	5	30	0	50	208.5	88.0	42.2

The compiled diagram shows that the "cost" of executing the next work order is largely influenced by the priority of the application and the flag if Technician is not assigned to the Service Territory of the current Service Appointment.

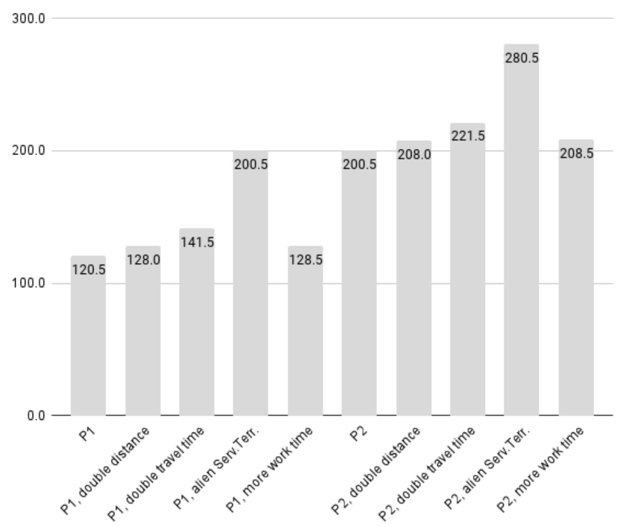

Fig. 4 *Diagram of the dependence of "costs" when selecting an order for execution.*

Thus, the algorithm calculates costs for all service appointments with "New" status and assigns them to the Technicians with the lowest cost value as the most valuable in terms of material and time costs, as well as value according to the priority.

Next, the algorithm is repeated for the remaining undistributed service appointments.

6. Model testing results

When testing the model in practice, it proved that the proposed algorithm makes the order of service appointments in such rule: the lowest cost service appointments are placed first for execution.

Costs include not only real material and time costs, but the number of appointments can be done during the day (e.g. two short service appointments have less costs than one during the same time).

It is displayed on the Dispatcher panel in graphical form:

Fig. 5 *The graphical representation on Dispatcher Dashboard for one Technician.*

The figure clearly shows the timescale of working hours, during which time periods are planned for performing work and for moving the Technician to the place of work.

Similarly, when using this cost estimation technique, a schedule of all active Technician is drawn up:

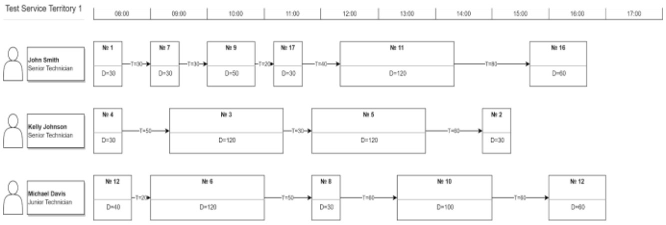

Fig. 6 *The graphical representation on Dispatcher Dashboard for many Technicians.*

The figure schematically shows the work schedule of employees belonging to the “Test Service Territory 1” Service Territory. The Dispatcher has the ability to make adjustments to the schedule using Drag&Drop technology and simply moving blocks of work both along the timescale (horizontally) and between Technicians (vertically).

After such changes, the dispatcher module automatically updates Scheduled Date/Time on service appointments and informs customers about changes via SMS messages.

In case if significant changes happened, the dispatcher module algorithm is executed again to re-calculate “costs” and rearrange Service Appointments on the Technician schedule.

. Testing in practice

This system was used in practice with a real organization - an Internet service provider (ISP) [10]. Its work orders included maintenance of client equipment and modernization of the core hardware owned by ISP. The capabilities of the system gave positive feedback from both company personnel and clients during the test period.

As a result of testing, it was found that for high-quality implementation of the system it is necessary to carefully analyze the division of the city into service areas and empirically select the coefficients of the dispatcher module. The latter is necessary due to various dependencies not taken into account in the current model. For example, the presence of traffic jams and their dependence on the time of the day, the density of urban development and parking restrictions in the city streets for official vehicles.

There is a need to add the breaks for Technicians for the lunch and the rest in the middle of the day in future modelling.

8. Conclusion

Based on the results of the article, it can be seen that the developed methodology for modelling a FSM system completely solves all tasks assigned to it and makes it possible to use the maximum of the advantages of the selected modelling technology.

The FSM system, developed on the basis of the proposed methodology, made it possible to bring FSM service to a qualitatively new level. The analysis of system data within the framework of the model allowed us to note the following positive achievements:

- Automated dispatch of requests has been implemented;
- The quality of task completion has increased;
- The deadlines for completing service appointments have been reduced;
- Ensures that “temporary repairs” and subsequent “permanent repairs” are tracked in one main work order;
- Places (equipment) that most often require technical intervention have been identified.

Important information on identified problem areas made it possible to plan preventive work at problem sites and optimize the work of the organization as a whole, reducing costs.

The FSM system has made it possible to increase the transparency of service at all stages of processing customer requests, increased the speed and efficiency of informing the customer about departure and rescheduling of the visit (in case of a delay at the previous facility) automatically via SMS messages.

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