UDC 004.942: 631.15

V.V. LYTVYNOV*, I.V. MYKHAILIUK*, A.S. POSADSKA**

FUNCTIONAL FEATURES OF DISPATCHING CONTROL CENTRE FOR AUTOMATIC CONTROL SYSTEM OF AGRICULTURAL ENTERPRISE

*Chernihiv National University of Technology, Chernihiv, Ukraine
**Chernihiv State Institute of Economics and Management, Chernihiv, Ukraine

Анотація. *Досліджуються проблеми побудови системи оперативного диспетчерського управління для сільськогосподарського підприємства. У статті розглядається вибір функціональності підсистеми оперативного диспетчерського управління, яке дає можливість мінімізувати втрати, пов'язані з несвоєчасним і неякісним виконанням виконавчого плану. Також представлене завдання забезпечення своєчасного та якісного реагування на непередбачені події.*
Ключові слова: *диспетчерське оперативне управління, автоматизована система управління, події атак.*

Аннотация. *Исследуются проблемы построения системы оперативного диспетчерского управления для сельскохозяйственного предприятия. В статье рассматривается выбор функциональности подсистемы оперативного диспетчерского управления, которое позволяет минимизировать потери, связанные с несвоевременным и некачественным выполнением исполнительного плана. Также представлена задача обеспечения своевременного и качественного реагирования на непредвиденные события.*
Ключевые слова: *диспетчерское оперативное управление, автоматизированная система управления, события атак.*

Abstract. *The problems of construction of dispatching control system for agricultural enterprise are investigated. The selection of the functionality of dispatching control subsystem, which allows minimizing losses associated with low-quality and untimely implementation of issues of executive plan is considered in the article. The task of providing timely and qualitative response to unforeseen events is presented.*
Keywords: *dispatching control, automated control system, events of attacks.*

1. Introduction to the topic of the study

Formulation of the problem. There is a tendency to use computer-integrated systems of automatic control in the agricultural enterprises of Ukrainian agricultural holdings. Automation concerns such areas as finance and economics, planning, precision agriculture, logistics, but it is absent in such area as dispatching, because of the difficulty of formalizing a number of processes that take place in the control object. At the same time monitoring of agricultural activity, control of quality of their implementation, and reactions on extraordinary situations are the factors, which greatly impact on implementation of issues of executive plan, their quality and timely implementation. Accordingly, economic effect depends on these factors. So, dispatching control becomes one of the most important systems in controlling processes in agricultural industry.

Analysis of related researches and publications. In the market of automatic control systems dispatching is well represented for such areas of the national economy as power supply systems, railways transportation, urban transportation, air lines, technological processes of enterprise control.

There are a lot of approaches to implement such control, for example ERP, MES, etc. [1, 2].

However, only a few software products partially cover the dispatching functions, and often the main emphasis is done on information and analysis and geoinformation parts.

In Ukraine, the majority of dispatching control functions for agriculture is presented by GPS monitoring systems [3]. Logistics subsystems are often included in GPS monitoring systems. In the most cases, headships of agricultural companies stop the efforts on equipping of the mobile technique by tracking devices for monitoring system. The tasks of primary data analysis, creation of possible solutions for problems appeared, and selection of one of them are performed by operator.

The aim of this work is to select the functionality of dispatching control subsystem, which allows minimizing losses associated with low-quality and untimely implementation of issues of executive plan; to provide timely and qualitative response to unforeseen events.

2. Features of automation object

The modern agricultural enterprise is complicated distributed system, which consists of many other different control objects. Functioning of this system is directed to growing of agricultural production, which depends on impact of external factors (weather conditions, social environment, etc.) [4].

Automated control system (A&C) of agricultural enterprise is adaptive system. It means that A&C must autonomously determine the best mode of operation depending on many values of internal and external factors [5].

One the other hand, it coordinates efforts for implementation of the executive plan (EP). On the other hand it performs a coordination activity that minimizes losses from deviations from the EP, which arise for various reasons.

Events-initiators of deviations from EP will be called as deviation events.

Generally, service of dispatching control (D&C) is provided in structure of A&C of agricultural enterprise.

The basis for the operation control is EP, which is created for a small calendar period. It contains a list of agricultural operations, which must be executed, and their due dates.

The essence of operation is depicted in flowsheet. It depends on the field conditions and job order of its implementation and is added to each of agricultural operations of EP [4].

So, it is assumed, that each agricultural operation or work, which is included in EP, is linked with one field and one flowsheet and has certain temporal borders of implementation.

Flowsheet determines the order of implementation of agricultural operations, necessary machine resources for its implementation, normative indicators of quality of operation implementation. Corresponding marks are added to the EP, when work instructions are violated.

The start signal of the operation is extradition of job order to perform certain operation and the issuance of the flowsheet for its implementation, which is permissible to be provided in paper or electronic form.

The suspension signals, resumption signals or cancellation signals of agricultural operation and correction signals of technological operation can be received by implementer as formalized messages or instruction orders sent from control centre by a variety of communication channels. After receiving these signals implementer has to confirm their receipts.

The graphical form of the process of operational plan correction is represented in Fig. 1.

The external factors, which could violate the EP, permanently affect on control object (CO) during the EP implementation (X is a set of external affecting factors). In monitoring mode, this system of dispatching control compares the state of CO and EP task. When an external factor violates the EP, dispatching control system detects deviation event. The next step is reaction that is formed on event – the control signal (Y is command and control information that regarded as correction of deviations of implementation and quality of EP issues reasoned by external affecting factors.

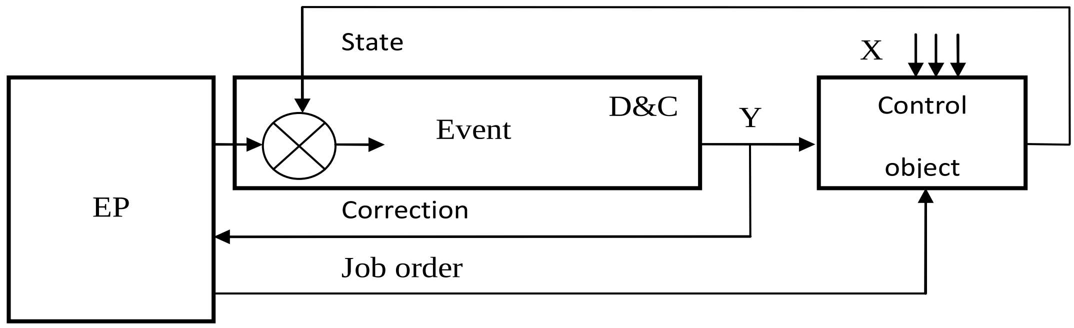

Fig. 1. The operative process of EP correction

According to requirements and specific of A&C of agricultural enterprise, dispatching subsystem must provide:

– control of EP implementation, including the provision by resources of points of its implementation;

– quality control of agricultural operations and overall quality of work implementation (quality assurance);

– harvest and resource protection needed (minimization of losses due to weather, pests, diseases, thefts of resources and harvest, etc.).

3. Requirements for subsystem functionality

Based on A&C features the basic requirements of functionality of D&C subsystem can be formed:

– automation of identifications of problems that need an intervention of dispatcher;

– automation of production of variety of problem solutions.

Thus, the dispatcher is responsible only for a specific decision-making from a list proposed by the system.

One of the main factors for choosing functionality of the system within the adaptive control is a factor of system response time on adverse events.

Let's consider the process of solving problems caused by external or internal events (Fig. 2).

As it is mentioned above, external and internal factors lead to deviations of EP implementation. Due to appearance mode all events can be classified as external and internal events.

The external events include events which are connected with: technique (breaking); staff (health, injury, delay certificate); breakdown of supplies (fuel, seed, fertilizer, technique); weather conditions (floods, rain, rainfall, drought, hail, sat, high wind speed, acid rain, thunderstorms, tornadoes, high or low temperature, frozen); condition of field (erosion, abnormal NPK, humidity, temperature, snow cover, changes of geometry); state of growing (infection by pests, stage of growing, the quality of cultivation, diseases, weeds); traffic conditions (speed limits, weight restrictions, road surface, road accidents, road closures due to protest movement, direction changes due to road repairs, traffic mashes); overload of storage of raw materials, etc.

For external events time delays for solution creation (t_{sc}), is equal to:

$$t_{sc} = t_{pdc} + t_t + t_{pp} + t_{ed} + t_q + t_{se} + t_{gs} + t_{dm} + t_{ep} + t_{td},$$

where t_{pdc} – time spent on primary data collection;

t_t – time spent on transfer of information via the communication channels;

t_{pp} – time of pre-processing and storing of information;

t_{ed} – time spent on event distribution to operators;

t_q – time spent on staying of event in the queue;

t_{se} – time spent on selecting of events from the queue;

t_{gs} – time of generation of variants of problem solutions;

t_{dm} – time of decision-making by dispatcher;

t_{ep} – time of correction of the EP;

t_{td} – time of transmission of decision to the implementer.

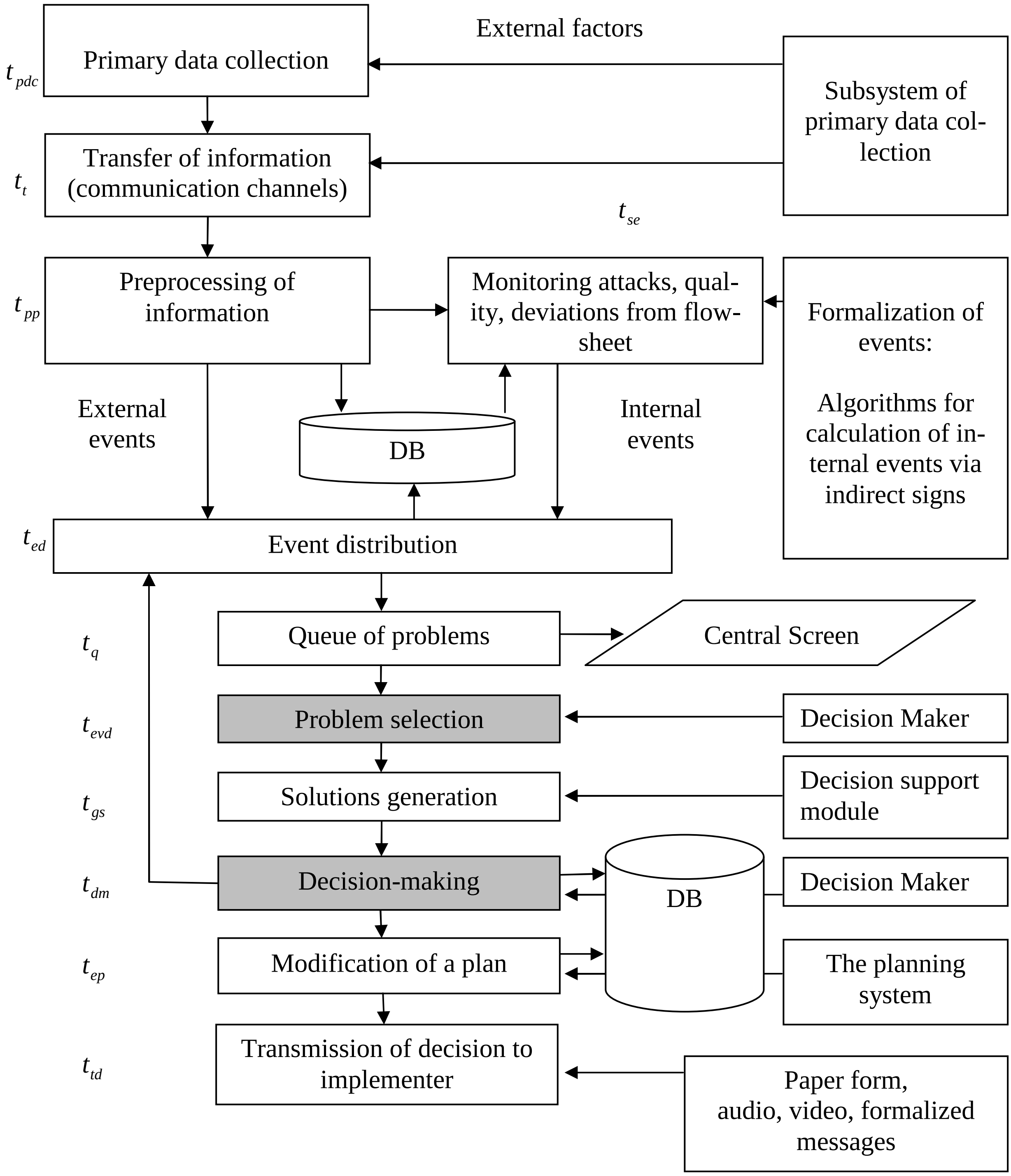

Fig. 2. Creation of reaction of disturbing events

Internal events include: events of attacks; events related to violation of operations implementation. These are all events, which are detected based on indirect evidence, obtained during the analysis of primary and archival information.

The reaction time (delays) for such type of events is equal to:

$$t_{re} = t_{pdc} + t_t + t_{pp} + t_{ed} + t_q + t_{se} + t_{gs} + t_{dm} + t_{ep} + t_{td} + t_{evd},$$

where t_{evd} – time of event detection according to indirect signs.

In classical case dispatcher spends most of time for generation of variants of solutions and their ranking. It increases the time of staying of events in the queue, and leads to decrease of response rate and quality of decisions. To reduce the reaction time for event, it is necessary to reduce each component using a new approach – automation of dispatcher actions.

Reaction time t_r can be written in such form:

$$t_r = t_1 + t_2 + t_3,$$

where $t_1 = t_{pdc} + t_t + t_{pp} + t_{evd} + t_{ed}$ – time spent on detection of event, $t_2 = t_q + t_{se} + t_{gs} + t_{dm} + t_{ep}$ – time spent on decision-making, $t_3 = t_{td}$ – time spent on transfer of orders to implementer.

To reduce reaction time it is necessary to:

– create formalized messages, classify events;

– create applications that generate variants of decisions and their ranking characteristics;

– design the analysis modules (analysis of primary information should not be performed by dispatcher);

– create automatic quality control systems;

– design systems with duplex communication between implementer of operation and dispatcher;

– create automated systems for detecting violations of technological process, thefts.

4. Structure of D&C subsystem

The proposed system of dispatching operational control should include the dispatching centre, primary data collection subsystem, the subsystem of transfer the orders, instructions and warnings [6].

Dispatching centre must be equipped with computing equipment, audio and video communications system, user's workstations (WS dispatchers, operators), and developed visualization tools of shared information.

Subsystem of primary data collection should be implemented as a network of peripheral equipment which is connected to the control centre by radio channels, including sensors, signal generating devices, which are served by microprocessors and peripheral computers.

Peripheral equipment must include trackers, RFID-systems, video surveillance systems, special Palm systems for quality control, remotes to enter and send signals, automatic weighing systems, express analysis tools, etc.

Potentially, the peripheral equipment can be static or mobile, which is installed on agricultural machines.

The system should be designed using modular approach (Fig. 3). Each module implements one or more functions of the system. All modules can be divided into three groups:

1. Group of users modules, which are intended for data visualization and input into the system: module «central screen» (MCS), workstations dispatchers, administrator workstation.

2. Group of D&C subsystem modules, which are included in the system core: module of events distribution (MED), module of attacks detecting (MAD), module of plan implementation monitoring (MPIM), module of monitoring of possibility of the plan implementation (MMPPI),

module of monitoring the operations quality (MOQ) and decision support module (DSM) for dispatchers.

3. Group of subsystems that ensure the functioning of A&C agricultural enterprise:

reference data and infrastructure subsystems, subsystem of primary data collection about control object, subsystem of works planning of crop production and their resource maintenance, logistics subsystem, subsystem of cartography, notification and exchange subsystem of urgent reports and orders between the control centre and implementers, subsystem of simulation of farm business.

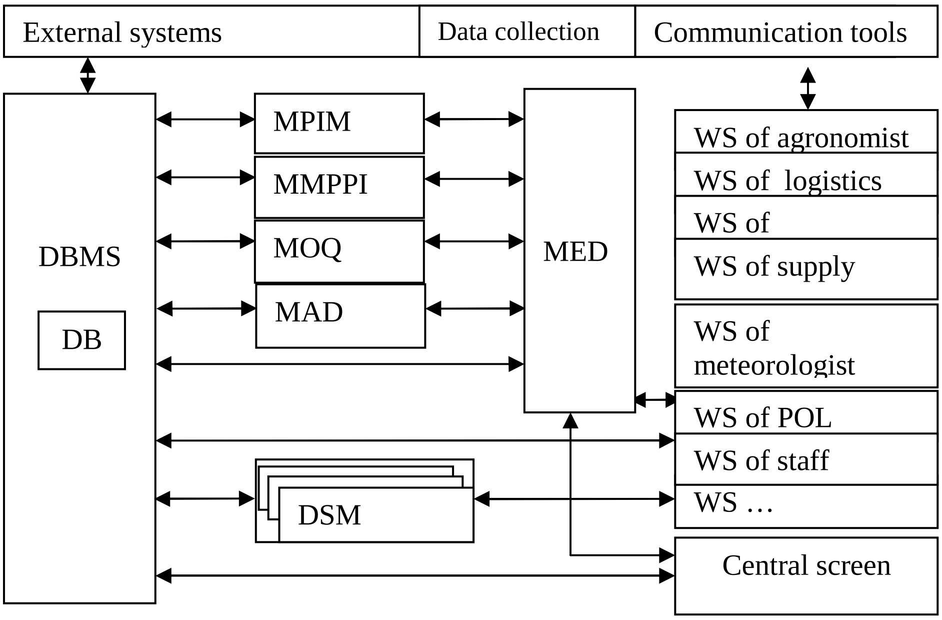

Fig. 3. Structural scheme of D&C subsystem

Dispatching system belongs to a class of systems, each work is based on the principle of reaction on deviation. It is means that the system should carry out monitor operation of EP implementation and involve the operator into problems solutions only when it detects a deviation from normative behavior of the control object.

It means that when adverse situations, which put in jeopardy well-timed and quality EP implementation, arise, it is necessary to create queues of problems, which are expected solutions. These queues are distributed by dispatcher's directions. Here it is possible to use two operating modes, which involves interventions in the process of EP implementation only in case of problem appearance.

When we put the process of monitoring of agricultural operations implementation, which are included in the EP, on automation, it causes that two different operating modes are used in the modules:

– part of module works in monitoring mode (with periodic start);

– part of the modules can work in mode of single start when event is appeared.

Periodicity of start of modules, which operate in monitoring mode, can be configured.

Modules of generation of solution variants, which are performed on the request of the operator or dispatcher, also operate in a mode of single start.

5. System settings functionality to fit the staff roles

Dispatching centre is a comprehensive and multi-user system. To determine the requirements for its functions it is necessary to start from the role-playing features of staff.

Table 1 shows the list of possible roles of staff and a brief description. For each role the specific workstation and applications should be implemented and developed, which perform support in decision-making, including the formulation of options and their ranking to facilitate selection.

Table 1. User Roles of dispatching centre

№	Role	Role description
1	Chief dispatcher	Responsible for quality of work of dispatching shift
2	Agronomist – dispatcher	Responsible for the operational control of processes of preparation of fields for planting, sowing and cultivation of agricultural crops, harvesting
3	Logistics dispatcher	Responsible for the operational control of using transport during the transport operations, monitoring, and analysis of the state and entering data about roads and vehicles in the system
4	Operator – technologist	Binds agricultural operations flowsheet with the geometric dimensions of the field, the available technique, the state of the soil, the current weather conditions, the state of the crops
5	Supply dispatcher	Controls ensuring of plant protection agents (PPA) operations, seed, fertilizers and other resources
6	POL dispatcher	Implements operational control of petroleum, oil and lubricants (POL) resources, including the monitoring of procurement and transportation of fuel, distribution of its storages, POL collateral control of all agricultural machines and mechanisms used in the implementation of agricultural operations
7	MRO dispatcher	Responsible for the operational control of MRO of agricultural machinery and the allocation of equipment to implement agricultural operations
8	Operator – meteorologist	Implements processing of meteorological information from various sources, and makes short-term forecasts for the period of the executive plan
9	Operator for staff management	Makes appointments of personnel to implement agricultural operations of executive plan

However, it does not mean that one role is performed by one dispatcher. Sometimes it is necessary to assign several roles for one dispatcher, or one role is needed to be assigned for several dispatchers. Everything is determined by a flow of messages between the implementers and dispatchers, performing a certain role and by degree of staff training.

To determine the most efficient use of the staff it is necessary to have flexible tools to configure the system. In particular, to highlight the types and number of dispatchers in the shift, the theory of queuing systems (QS) can be used. Since each dispatcher decides a certain circle of coming problems (events), that enter the system online, he can be interpreted as an instrument of service, working with applications of a single queue. The system configuration can be reduced to the task of calculating the characteristics of QS [7].

Model of QS, which associated with the service queue of requests, includes:

– input flow of events;

– service channels (WS).

Complicated service system is represented in Fig. 4.

The main characteristics for tasks of QS are:

λ – the intensity of the incoming flow;

μ – the intensity of service events;

m or n – the number of serving devices of the same type.

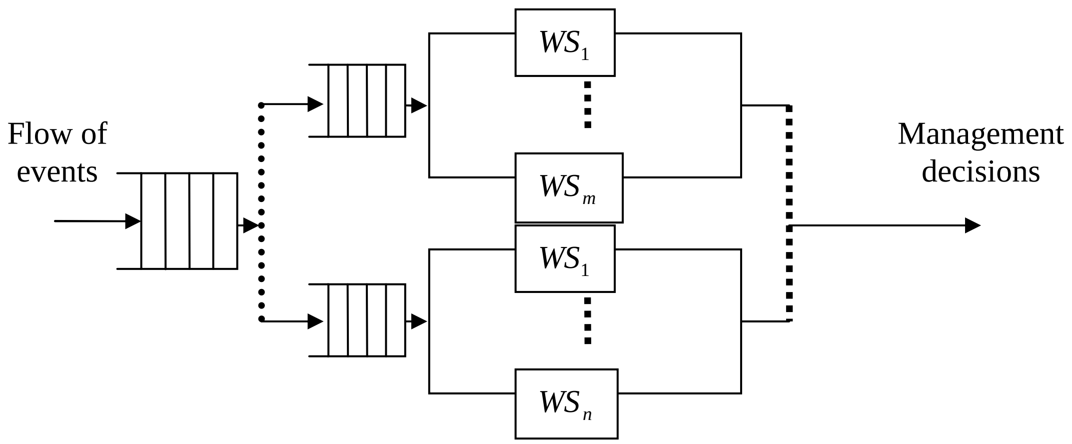

Fig. 4. Complicated service system

Creation of simulation model based on GPSS or Anylogic should allow calculating following indicators of system:

– the average time, which the event is waiting for the service beginning;

– the average service time of the event;

– the number of dispatchers in the shift.

6. Modules of generation of hidden events

Previously mentioned modules, such as module of attacks detecting (MAD), module of plan implementation monitoring (MPIM), module of monitoring of possibility of the plan implementation (MMPPI), module of monitoring the operations quality (MOQ), have a certain property, that when they analyze primary data, they become sources of events, which require operator intervention, themselves.

Generally they are built using rules such us:

<u>If</u> P <u>Then</u> Q,

where P – predicate of precondition implementation;

Q – predicate of generation of hidden events.

Depending on the type of modules, the source of information, serving to build predicate P, can be: for MOQ – it is data of flowsheet (recommended modes and formulas of assessing operations quality), for MAD – they are unplanned stops of transport, that allow draining fuel, or deviations from the agreed route during harvesting, for MMPPI – it is information about the level of resources reserves, and time their completions (fuel, seeds, capabilities of car park, etc.), for MPIM – it is information about unfinished works.

All these modules work in monitoring mode and for planning their starting it is reasonably to have the tools such as calendar in simulation systems of discrete systems [8].

7. Modules of generation of solution variants

Generation of problems solutions is closely associated with events-indicators, which accumulate in the problems queues [8].

Modules, that generate solutions variants, may be described as:

$$\underline{\text{If}}\ Q_i\ \underline{\text{Then}}\ R_{i1} \vee R_{i2} ... \vee R_{im},$$

where R_{ij} – predicate-indicator of j-th solution, $j = 1...m$.

Ranking function of solutions Q_i related with the set of solutions for event:

$$F_i : R_i > N,$$

which allows to calculate their quality characteristic. Sometimes it is rationally to receive this function using method of expert evaluations.

8. Decision support module

Purpose of DSM is decision support in abnormal situations (events), which can violate the EP. DSM consists of:

– user interface;
– users;
– editor of knowledge base;
– experts;
– knowledge engineer;
– knowledge base;
– inference engine;
– subsystem of explaining solutions;
– modeling unit.

Mathematical modeling may be represented as shown below.

1. Method of Hierarchy analysis [7]:

– formulation of the problem (for example harvesting);
– identification of criteria for evaluating alternatives options for solutions;
– pairwise comparisons of criteria (Table 2):

Table 2. Pairwise comparisons of criteria

	A_1	A_2	...	A_n
A_1	1	a_{12}		a_{1n}
A_2	a_{21}	1		a_{2n}
…			…	
A_n	a_{n1}	a_{n2}		1

where $A_1, A_2, ..., A_n$ – criteria for evaluating alternatives;

a – evaluation of compared factors.

2. To formalize the multicriteria problem the algorithm of multicriteria evaluation of alternatives solutions is applied:

– define the criteria for evaluating alternatives;
– rank the most important criteria;
– discard unimportant criteria;
– assign a number that corresponds to the relative importance of the criteria;
– normalize coefficients (w_i) in importance from the condition:

$$\sum_{i=1}^{n} w_i = 1,$$

where w_i – weight *i*-th criteria, which assigned with decision-maker;

– make preliminary bolting of alternatives by quality (defined quality index on the scales of criteria);
– determine the utility function U for each criteria

$$U = \sum_{i=1}^{N} \left[\frac{x_i - x_i^*}{x_i^*} \right]^2 ;$$

– determine the usefulness of each of the alternatives of the formula:

$$U = \sum_{i=1}^{N} w_i U_i .$$

Based on the obtained results, the decisions with highest usefulness of alternatives will be considered for selection of final decision.

9. Example of usage of dispatching system functionality for the tasks of «best route search»

1. Formalized message about event arrives to the control centre (the message «parent») – «road congestion», which causes perturbation of the system.
2. Message appears on the central screen and on workstation of dispatcher, who is responsible for this type of event - that is logistics dispatcher.
3. Dispatcher chooses this message from the queue of problems and starts DSM, which creates lists of tasks and possible problem solutions. Task list is automatically generated after choosing certain solution in the system (that are presented as messages, which are «children» from «parent» messages): correction of executive plan, transmission of decision to the implementer (driver).
4. After all problems are solved, the message is marked as completed, the status of the event «parent» is changed to «solved». This event is deleted from the list of problems and goes to archive.

Scheme of solution of such problems is presented in Fig. 5.

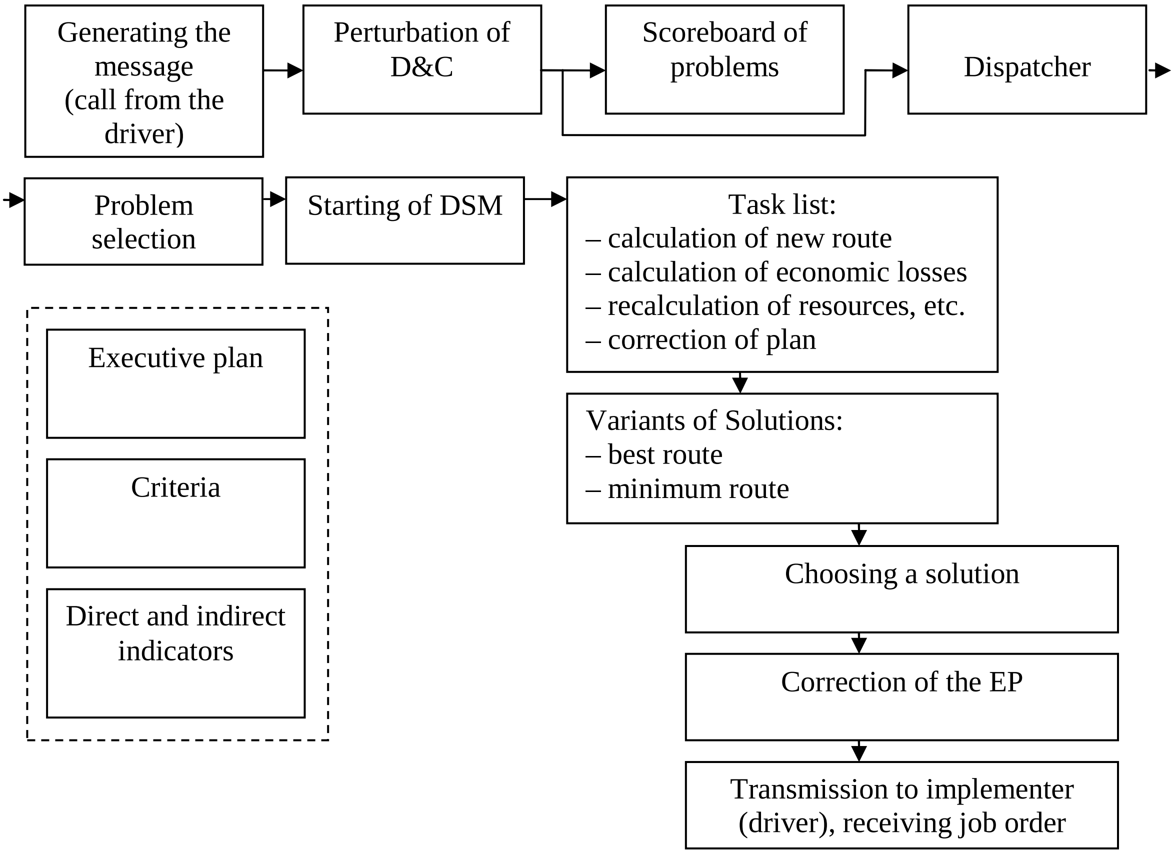

Fig. 5. Scheme of solution of logistical problem

This example is an example of reaction on external event. In monitor mode, the system constantly identifies deviations or violations that lead to the appearance of a new event. For example, the driver violated the speed limit or module of detecting attacks suffered a deviation from the route according to the data of tracking or violations of quality of operation implementation. Then the message of particular event will be transferred to dispatcher, and the job scenario will be analogous to steps 1–4.

10. Conclusions

The concept of design of D&C subsystem for the agricultural firm, which is offered by the authors, fully reveals the main aspects of adaptive control of A&C. The main purpose of D&C is the automation of process of distribution and primary processing of data about the state of the fields, crops and agro-firm resources, decision support dispatchers.

Dispatching efficiency is based on the systematic monitoring of the executive plan implementation, and takes immediate action and solves problems. This makes it possible to implement the automation of agricultural enterprise and information technology to reduce financial costs, minimize the influence of human factors on the course of normal operation of farm business.

REFERENCES

1. Enterprise Resource Planning System [Online] [Електронний ресурс]. – Режим доступу: http://www.cmdsoft.ru/information_systems/erp/what_is_erp_system.

2. MES-системы [Online] [Електронний ресурс]. – Режим доступу: http://mescontrol.ru/articles/systems.

3. Гринчак О.В. Особливості управління сільськогосподарським виробництвом / О. В. Гринчак, О.Х. Давлетханова, Я.Л. Миколайчук // Зб. наук. праць Уманського НУС. – 2012. – Вип. 78, Ч. 2 (Економіка). – С. 198 – 204.

4. Бальченко И.В. Особенности построения автоматизированной системы управления сельскохозяйственным предприятием / И.В. Бальченко, В.В. Литвинов, В.П. Клименко // Математичні машини і системи. – 2013. – № 4. – С. 82 – 94.

5. Литвинов В.В. Особенности информационных технологий управления сельскохозяйственным предприятием / В.В. Литвинов, И.В. Бальченко, В.П. Клименко // Вісник Чернігівського державного технологічного університету; наук. зб. – (Серія «Технічні науки»). – Чернігів: Черніг. держ. технол. ун-т, 2013. – № 30 (67). – С. 211 – 218.

6. Непомнящий Е.Г. Планирование на предприятии: конспект лекций / Непомнящий Е.Г. – Таганрог: ТИУиЭ, 2011. – 124 с.

7. Томашевський В.М. Моделювання систем / Томашевський В.М. – К.: Видавнича группа BHV, 2005. – 352 с.

Стаття надійшла до редакції 31.07.2014