Modelling and Prediction of Logistic Chains Dependability Using the Markov's Random Processes

MILAN VROZINA[1], VILEM SROVNAL[2], JIRI DAVID[1], ZORA JANCIKOVA[1]
[1] Department of Automation and Computer Application in Metallurgy
[2] Department of Measurement and Control
VŠB-Technical University Ostrava,
17. listopadu 15, Ostrava-Poruba, 708 33,
CZECH REPUBLIC

Abstract: The ways of the plant management with computer aid are described where the boundary of the system managed can be outlined, on one side, in supplying and, on the other side, in sale. In the framework of system defined in such a way the logistic chains are defined, the types of these chains are differentiated and the method of their dependability investigation is proposed. The chains creation in maintenance management is emphasized. For modelling of dependability in time the Markov's random processes are utilized.

Key-Words: Logistic chain, Modelling, Prediction, Random process, Computer integrated manufacturing

1 Introduction

With implementation of philosophy of computer integrated manufacturing (CIM) the range as well as the way of the system controlled is being extended both on the enterprise and on wider inter-company level. This system is defined from inputs which are created by suppliers up to output which is created by the customer's requirements. The system approach to analysis and management of systems defined in such a way permits to apply the logistic understanding, to determine the logistic chains in the structures and to deal with their characteristics in the sense defined in advance. The following contribution will be devoted to problems of dependability of logistic chains outlined.

For the purpose of logistic chains dependability investigation we will accept the definitions of basic terms from the sphere of logistics, e.g. from [1].

2 Automated management systems, definition and characteristics of logistic chains

In earlier understanding of the enterprise management the strict hierarchic breakdown of its activities was saved with which also the selected technical means of automation on single levels corresponded. This situation can be presented with the help of Fig. 1.

It is necessary to take into account the existing trends in the enterprise management as a whole when the computer technique penetrates into all enterprise departments. The CIM philosophy can be considered as the penetration of two information flows. The vertical flow represents the data oriented technologically, representing the design and construction (CAD-Computer Aided Design) and ensuring of direct management of technological process (CAM-Computer Aided Manufacturing). The horizontal flow representing the planning, transport, supplying, marketing, trade, finance, personnel matters etc. The penetration of both flows than is expressed by CIM management ensuring, in its consequence, the multi-purpose optimization of final product.

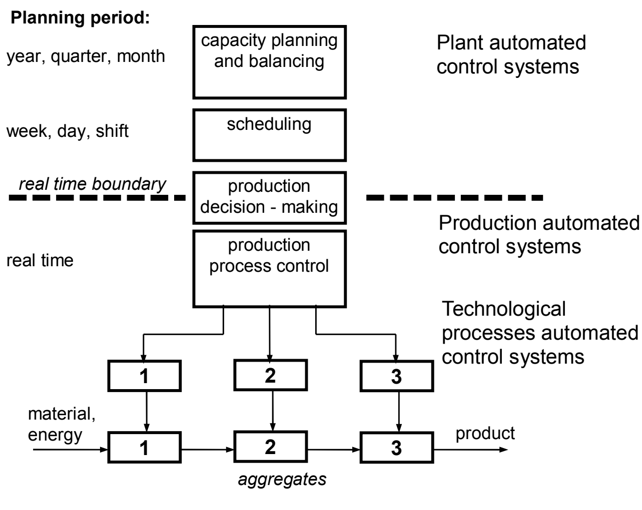

Fig. 1: Structure of automated control systems in plant

The computer aid of management realizing conception is illustrated according to Fig. 2, provides a sufficient quantity of documents for extension of the system managed in such a way so that its input values would be the information from suppliers and the output ones than the data from customer where also the required values of the process controlled are created. [2]. The system understanding of this task solution permits to define the logistic chains in the system structure enabling effective solution of these problems, its continuous improving in the process of gradual integration as well as utilization of efficient software means determined for modelling and management of logistic chains as the discontinuous systems.

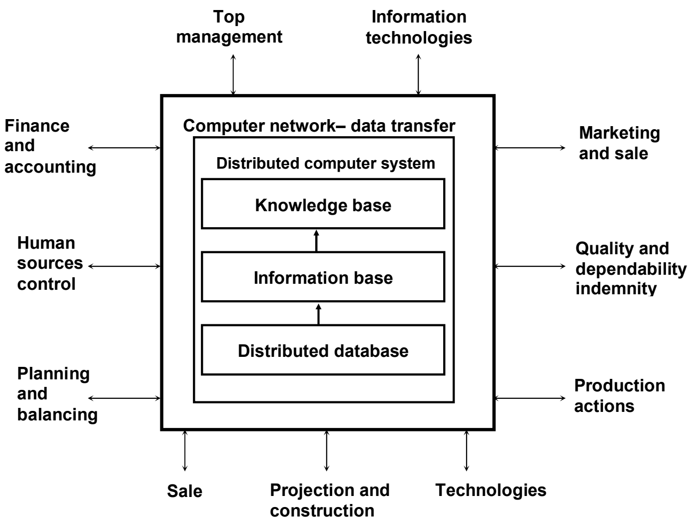

Fig. 2: Plant control according to philosophy CIM

The logistic approach to solution of given problem management requires the orientation on the customer's needs who is the final target of material flows and also the decisive source of information necessary for this management from the viewpoint of final production. At the same time, the solution from the viewpoint of this final production is focused on coordination, synchronization and optimization of all material as well immaterial processes which are connected with delivery of final product to customer, and namely from the viewpoint of time consumption and economy under keeping of requirements on total quality.

It is necessary, for realization of these intents, to define the logistic chains on logistic system as the dynamic interconnection of partial systems – chain elements – corresponding to division of work where due to coordination, synchronization and optimization of functions and structures the flexible and economic achieving of final target is possible at reaching the maximum synergic effect.

The elements of logistic chain themselves can be considered as the individual logistic subsystems with the possibility to define the own logistic chains. Their behaviour, however, must be influenced in favour of global criterion set together for all chains of logistic system.

In practice, the chain elements can be created e.g. by suppliers, purchase, transport, storage, production, sale, customer etc. These chains contain both passive elements as raw materials, stores, manufacturing machines etc. and active elements as handling means, control systems etc. which enable the handling, regulation and optimization on local level of particular elements but also effective synchronization and coordination of logistic chains managed from the central level. From the viewpoint of dependability then the contact places between the elements (interface) which are the sources of information for calculation and modelling of dependability indicators are important.

Three types of basic logistic chains exist:

– Classic chain working according to push principle, where preceding component sends products to subsequent component, which it created according to agreement in amount and time, which fit it. The method is accompanied by a larger amount of store both on the side of supplied raw materials and subcontracts and on the side of finished products. Information propagates in the chain by serial means.

– Chain with continual flows working according to pull principle, where a method JIT (Just in Time) uses at product deliveries, when preceding component supplies its products to subsequent component only in the moment, when it is ready to accept them. Stores on the side of raw materials supplies and subcontract fall off, stores on the side of finished products remain. Information flows have again serial character.

– Chain with synchronous flow, which works on symmetry principle, when only minimally necessary amount of raw materials or products is found in each moment inside and between the chain components. It is possible in consequence of parallel information flow and existence of control component of the whole chain ensuring synchronization, coordination and optimization of all processes in the chain according to the model, which creates in the real time simulation of all possible states and permits to choose an optimal solution variant for the realization. Block diagram of such chain control is described on Fig.3.

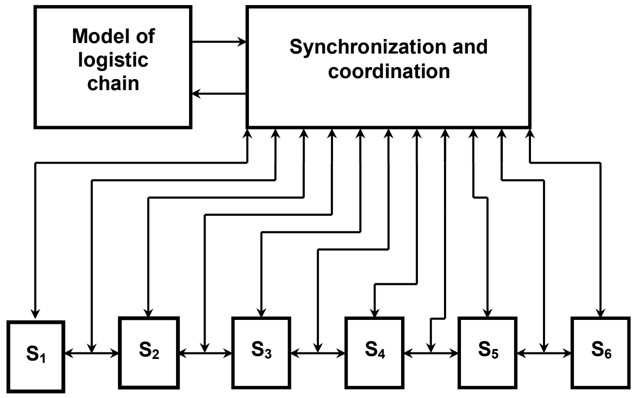

Fig. 3: Logistic chain with synchronous flows

Logistic chains with synchronous flows are the most advanced type of chains. The tendency is to move gradually from less perfect to more perfect chains. It is an integration process of the logistic system. Concrete methods of this integration are termed as „reengineering".

3 Modelling of logistic chains dependability

Dependability of the object, which also a logistic chain can be, is defined according to ISO 9000 as availability and factors, which influence it, are reliability, maintainability and maintenance support. With respect to the range and intention of the paper we note an important characteristic in logistic chains behaviour. They must fulfil requirements in terms of:

- timely delivery
- complete delivery.

These requirements must be accepted both between particular components and at the whole chain. As a reliability state we mark e.g. early delivery fulfilment. As a failure we mark default delivery in time. As a renewal time we mark repeated delivery fulfilment after preceding failure.

For expression of dependability indexes, their modelling and determination of a further development to the future (prediction) it is necessary to gain operational data about early fulfilment or default deliveries between particular nodes and also at the whole chain in time, including renewal times, to employ these data for determination of reliability and failure states probabilities in frequency terms, to determinate failure and renewal intensity and thus also conditional probabilities of transition of the chain from functional to non-functional state and to the contrary. However in the given case we can choose a process with a simple renewal, where renewal duration is considerably shorter than duration of reliability state. Thus we introduce further simplification. Similarly we can treat also at judging delivery completeness.

For creation of logistic chain dependability model in defined time period a modelling method on the basis of Markov´s random processes theory was chosen. It was chosen for the following reasons:

- it provides direct probable model of state behaviour,
- multi-state situations are easy processed by this theory,
- it is very useful for availability indexes calculations.

Disadvantages of this method are:

- it can become too complicated at a large number of states,
- it depends on the assumption that failure and renewal intensities are constant,
- only systems with gradual development of failures can be modelled by this method.

Markov's random process can be characterized as a function of two random variables: system state and tracking time.

Random process of Markov's type with a definitive set of states and continuous time is determined by the triad:

$$\langle S, \mathbf{D}, \mathbf{p}(0) \rangle \qquad (1)$$

where $S = \{s1, s2, ..., sn\}$; $2 \le n < \infty$ is set of states,
$\boldsymbol{D} = (d_{ij});\ i,j = 1,2,...,n$ is matrix of transition intensities
$\boldsymbol{p}(0) = (p_1(0), p_2(0), ..., p_n(0))^T$ is vector of initial probabilities.

Variable $d_{ij}\,dt$, $i \neq j$ determines a probability, that system, in which Markov's process proceeds and which is in a moment t in state s_i, transfers in infinite time interval $(t, t+dt)$ to state s_j

The solution of Markov's process, which is defined according to (1), is a vector equation:

$$\boldsymbol{p}(t) = \left(p_1(t), p_2(t), ..., p_n(t)\right)^T \quad t \in \langle 0, \infty) \qquad (2)$$

where $p_i(t)$ is probability, that system occurs in a moment t in state s_i

This function we can find as a solution of system of linear differential equations:

$$\frac{d\boldsymbol{p}(t)}{dt} = \boldsymbol{D}^T \boldsymbol{p}(t) \qquad (3)$$

which is completed by equation:

$$\sum_{i=1}^{n} p_i = 1 \qquad (4)$$

and with initial conditions given by a vector ***p(0)***.

Algorithm of the dependability model can be divided to the following parts:

- calculation of initial probabilities of dependability states of particular chain components,
- calculation of probabilities of particular states in chain and execution of their analysis.

At present the modelling is executed by means of software CARMS (Computer-Aided Rate Modelling and Simulation). It is application software of American firm DAINA Corporation for modelling and analysis of reliability, availability and maintainability of systems by means of models based on Markov´s random processes use. The models are created in graphics environment by means of diagram of Markov´s random processes states and matrix of transition intensities. Results of simulations are represented not only in digitally but also in graphic form.

As with increasing number of elements a number of states grows exponentially and thus also number of equations of solved differential equation system increases, it is useful to apply for solution factorization method of Markov´s random processes, that enables to decompose the Markov´s model of a complex system, in our case of logistic chain, to a hierarchical system of simple and well-realizable models. For use of this method a structure dependability model expressing dependability of particular components of the whole chain can be created.

Theory of Markov´s random processes was not in larger range practically employed yet especially from the reason of a hard solution of the compiled system of differential equations. At present state of technical means we can assume, that this theory will gain ground in different industrial applications.

Numerical characteristics of dependability indexes are achieved on the basis of given objects tracking. Statistic significance of dependability indexes estimation is dependent on a tracking time of the given logistic chain. The tracking time of the chain, or its components, can be determined by means of computer program SPOL_4, which was created on Department of Automation and Computer Applications in Metallurgy VŠB - Technical University of Ostrava. SPOL_4 is a computer program for determination of necessary tracking time of the chain [3].

The model was applied to a logistic chain in this paper. On the figure 4 a diagram of transient states of the modelled system is presented. State S expresses a functional state of the whole chain; states S1 up to S2 express failure states of particular chains. Edges of graph express probability of transitions from state S to states S1 up to S6. In the given case we can assume, that renewal times are significantly shorter than times of functional state. So a graph of transient states is a graphic expression of a logistic chain dependability model, on which we can gain also predictions of probabilities of its failure states in time. On the figure 5 results of simulation calculation of state probability of chosen object in dependence on time are described. Curve with downward trend expresses probability of reliability state of the whole chain; other curves express failure probability of particular components of the chain.

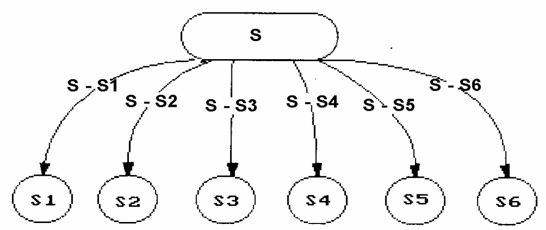

Fig. 4. Diagram of transient states of chain

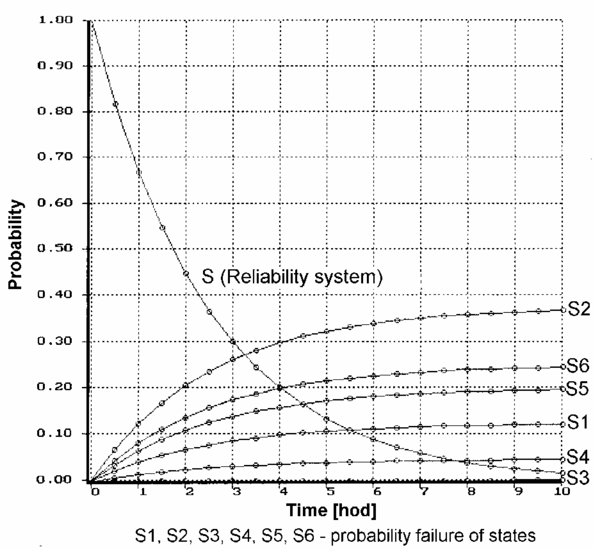

Fig. 5. Results of simulation calculations

At present source data about dependability of logistic chains in necessary range are not in disposal. This state does not permit to compile a practical application. Therefore an algorithm of dependability indexes determination from data file and above all from incomplete data files are elaborated.

4 Conclusion

On the basis of summary of present state at realization of plant automated control systems a logistic approach to analysis and control of system defined from its inputs on supplier's side up to outputs on customer side was chosen. Logistic chains were defined on selected logistic system. Logistic chain types were introduced, a method of their integration was stated and tracked dependability indexes were selected on the model of chain with synchronous flows. Markov´s random processes were used for dependability modelling and for determination of its prediction. Transient graph was created and on the basis of chosen input values simulation calculations of selected dependability indexes in time were executed as an illustration.

Using presented method of logistic chains dependability modelling rich knowledge from technical objects dependability modelling by means of Markov´s random processes could be utilized on Department of Automation and Computer Applications in Metallurgy [4], solved for needs of computer support of continuous steel casting process control and for needs of maintenance of this technological process.

Acknowledgement: The Grant Agency of Czech Republic supplied the results of the project 106/02/0086 with subvention. The Ministry of Education of Czech Republic supplied the results of the project J17/98:272400013 with subvention.

References:

[1] Pernica P., *Logistický management* , Česká logistická asociace, Praha 1998

[2] Yong-Za Lul, Meeting the challenge of intelligent system technologies in the iron and steel industry, *Iron and Steel Engineer*, September 1996, pp. 139 – 149.

[3] Bednařík L., David J., Vrožina M.: Analýza časového plánu preventivních prohlídek z hlediska výskytu poruch, *sborník XXI. semináře ASŘ´98 "Počítače v měření,diagnostice a řízení"*, VŠB-TU Ostrava, Ostrava 1998

[4] David J., Vrožina M.: Možnosti inovace řízení údržby zařízení pro plynulé odlévání oceli, *Hutnické listy* , No.7-8, 1999, pp. 67-71