The Optimal Management of Informational Servicing Logistic Systems

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Abstract

This paper reviews optimization problems of informational servicing logistic systems (ISLS) management in problems class, which can be solved by the queuing system (QS) theory. Examples of mathematics models building and effective algorithm development for quasi-optimal management of informational servicing logistic systems are presented.

Keywords

Logistics, logistic information management, computerized administrator-coordinator, computer logistic, mathematical models, structure.

The logistic systems concept

The logistics, as a cognition form, is known from the great antiquity. Originally, the art of rational measuring, skilled computing and logical conclusions were in its competence [1]. The logistic systems are creating for the purpose of the industrial and economic activity and the finance-economic activity coordination, based on the united coordinated organizational, informational, hardware and software maintenance, aggregate of interconnected sub-units of integrated systems. The logistic system of an organization-technological type includes: maintenance supply, stuff and component keeping, finished commodity production, goods shipping to intermediate warehouse, final sale and use of finished commodity.

The informational and computer maintenance of such kind of systems may appear in two hypostasis: first, as the informational or computer support of made decisions for a concrete type logistic system; secondly, as the independent logistic information management system (LIMS). In the second case, The LIMS, built on the base of special software, transforms the information from an auxiliary factor into an independent production force, which gives a possibility to essential increase of the the labor productivity and to minimize the production costs. It essentially increases the logistic organization-technological system's (OTS) functioning effectiveness.

The logistic is determined like a science about an integrated organization-technological management by the production, economical and information processes for the purposes of the total costs minimization from the non-coordination system's subunits functioning. The absence of needed interactions coordination between OTS subunits results in system's unbalance because of aspiration for private goals by separate subsystems [2, p. 12]. The basics of production and industrial, construction and transport, commercial and sale logistic are developed by now. The informational and computer logistics are in the stage of forming by now.

The logistic systems of industrial, commercial and transport types are quite enough represented on the world market of computer technologies. In this case, the universal corporate management systems R/3, designed by SAP located in Germany, completed by logistic units to execute next functions: material flows management, enterprise resource planning, suppliers market analysis, purchase and supply, warehouse management, exchange operations, account management, inventory. The concept of information openness supplies the possibility of detailed "self-control" on user's departments and subunits. As the OTS structuring result, the rational logistic decisions can be got for the logistic system, finance system, intra-economic activity analysis system and personnel management system.

The ISLS can be considered in a way as a computerized administrator-coordinator who organizes the rational work of a whole of interconnected IMS systems. They possess a solution of badly formalized problems of computer logistic usually places on specialized expert systems or computer network, database servers, electron coupling nodes administrators.

Issue 10, January-June 2007
p. 47-54

The logistic systems' structuring

The ISLS structuring problem consists in mathematical models development, methods and algorithms of rational analysis selection and system structure synthesis based on principals of decomposition-aggregation, identification-optimization and made rational decisions coordination for purposes of total effect receiving from the integrated system, which exceeds effect sum, taken separately from each system component. The problem of effective integrated structure forming for logistic OTS functioning in a common case belongs to the nonlinear accidental programming problems class:

$$S^* = \arg \underset{S \in S_D}{\text{extr}}\, E\left\{\sum_{i=1}^{k} \lambda_i \left[Q_i(S) - Q_I^*\right] / Q_i^*\right\} \quad (1)$$

where S_D = feasible region, which meets to material balance equation, order of information transformations, stages of quasi-optimal management decisions making; Q_1, Q_2, Q_3, = quality criterions, accordingly, for estimation of incumbent on system activities functions; fullness, reliability and timeliness of information receiving which needed for management tasks; total costs for concrete structure type design and exploitation; λ_i = criterions weights, at that $\sum_i \lambda_i = 1$; $E\{\bullet\}$ = average of distribution operator.

The formalization of problem (1) supposes the attraction of additional information about parameters and characteristics of structure synthesis process. Parameters are necessary for limits precise which aggregate determines the feasible region S_D. Operational characteristics observations let to determine the empirical frequency distribution and calculate the average of distribution operator $E\{\bullet\}$. The replacement of factual parameters and characteristics by basic data for design can give rise to sudden results. And so, in practices, the structuring is often content with reductive target settings and their decisions are finding with heuristic artificial procedures.

Every ISLS (system of collection, transmission and transformation of information) characterises by its integrated structure, which is described by service line number, possibility and discipline of queue formation, requirements of incoming flow number, queue service discipline. Information servicing systems are subdivided into single-line and multi-circuit systems, with waiting and breakdowns when the service line is busy, with limited queue by requirements number, by waiting time for servicing, etc. The rules used to select requirements for service, compose a service procedure. The most frequent occur disciplines, which realize the rule: "first in first out", group servicing and priority servicing. In the latter case here may be absolute, relative or mixed servicing priority. The message transmission, receiving and initial processing means by information flow servicing process.

The ISLS structure as the next five can characterize QS:

$$S_{base} = < I_{in}, I_{out}, T_{srv}, N_{srv}, P_{srv} > \quad (2)$$

where I_{in} = ingoing requirements flow, I_{out} = outgoing flow of serviced requirements, T_{srv} = servicing duration, N_{srv} = number of service lines, P_{srv} = service procedure (strategy).

The QS structure concept is one of the fundamental; it includes in itself next information: number and properties of ingoing and outgoing flows, possibility of queue and service procedure organization, ways to move requirements inside the system, number and interconnections of service lines. The ingoing flow and service lines parameters are described by the statistical and determinate time behaviours, which determine the interval between requirements arrival to system and requirement time processing into a service line. The service procedure, representing the logical characteristic, installs the ways of requirements passing through the system, the presence of storage service lines (buffer service lines), the requirements selection criterion for servicing (priority) and other correlation.

The direct and reverse logistics problems

All modelling problems, operation research and optimization of management by the logistic systems from the computing point of view, can be divided to direct and reverse problems. The problems of direct logistic are: management quality analyses problems as applied to integrated organization-technological systems using the aggregate if local indexes or generalised technical-economic index. These problems let to answer the question: how the selected effectiveness index will be changed during the transfer to new system stage taking into account a different display of environment. During the direct logistic problems solving the mathematical descriptions for all of interconnected sub-units of logistic system, an active model of mutual process coordination is developing, after it, procedures and algorithm of preferred decision-making based on the aggregate of fundamental technical-economic indexes are developing too. The formalized, badly formalized heuristic and non-formalized artificial procedures are used to get a computational solution of direct problems.

In reverse logistic problems it is necessary, by the given optimal set of qualitative indexes which meets to the corresponding value of criterion function or to the best in a certain sense conditions; to change the structure and parameters of a logistic system thus it will be functioning in modes, which are nearest to optimal. The reverse problems solving methodology (reverse engineering), first of all, issues the skill to solve direct problem (engineering) many times on some, previously determined, varying values of fundamental parameters. This method of a simple parameter varying lets to find a preferred decision in primary cases only. During the valuable number of possible decision variants the methods of the directional running over which provide the movement to wishful systems state using the consistent running over are applied.

The ISLS structure

The quality of a logistic system management in a considerable measure depends on a system's structure accordance with conditions of its functioning. The structure means an element set (production sub-units, sub-systems, problems), which is founded in relations and relationships with each other and form-determined integrity. The structure, in a narrow sense, reflects relatively stable and invariant regularities, related to an inner structure and system organization, and, in a wide sense, it concept is added by the functioning features, which reflect a specificity of relations between its parts, regularities of material and information flows distribution, etc.

Each system, which collects, transmits and transforms information, has its own organization, which characterizes by the number of service lines, possibility and discipline of queue constitution, number of ingoing flow requirements, service procedure. The QS can be single-lined and multi-circuit with waiting, breakdowns when the service line is busy, with limited queue by the requirements number, by the waiting period in a servicing, etc.

The rules used to select requirements for service, compose a service procedure. The most frequent occur disciplines, which realize the rule: "first in first out", group servicing and priority servicing. In the latter case here may be absolute, relative or mixed servicing priority.

The message transmission, receiving and initial processing means by information flow servicing process. The servicing process of information flow means transmission, receiving and initial message processing. In queuing theory under the servicing period is understood time spent to service one requirement by a given service line. This index characterizes the capacity of a service line.

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The ISLS effectiveness valuation

The reverse problem of ISLS optimization during the re-engineering (re-design to improve a system) of a terminal service line means getting answers to the next questions: how much time a subscriber waits for servicing; how probability the service line in a concrete moment occurs busy; how frequently the queue exceeds adjusted length?

Next indexes used to estimate functioning quality of the existing ISLS system: $\overline{n}$ = average number of messages per second, which is receiving for servicing (rate of ingoing requested flows λ); $\overline{t_s}$ = mean time of servicing in seconds (a backward value of a service rate $\overline{t_s} = 1/\mu$); $\rho = \overline{n t_s}$ = coefficient of service line utilization; $\overline{w}$ = average number of messages, which wait for servicing at the present moment; $\overline{g}$ = average number of messages, which wait for servicing and are being servicing at the present moment; $\overline{t_w}$ = waiting period by a message to service; $\overline{t_g}$ - time, spent by a message to wait for servicing.

Next correlations are correct between these values:

$$\overline{t_g} = t_w + t_s, \quad \overline{t_g} = \overline{t_w} + \overline{t_s}, \quad \overline{w} = \overline{n} \cdot \overline{t_w}, \quad \overline{g} = \overline{n} \cdot \overline{t_g} \tag{3}$$

next statistical indexes of service quality are determined from them:

$$\overline{g} = \overline{n} \cdot \overline{t_g} = \overline{g} = \overline{n} \cdot \overline{t_w} + \overline{g} = \overline{n} \cdot \overline{t_s} = \overline{w} + \rho \tag{4}$$

The average statistical values of these indexes appreciably depend on request distribution law, which received for servicing. The average number of requests, which wait for servicing, $\overline{w}$ determines by the Hinchin-Pollachek formula:

$$\overline{w} = \frac{\rho^2}{2(1-\rho)}\left[1 + \left(\frac{\sigma_{ts}}{\overline{t_s}}\right)\right] \tag{5}$$

where σ_{ts} = mean square (standard) deviation of in-service time $\overline{t_s}$ (usually, set like a initial data at design time).

Usually, the most typical, there are two boundary cases: uniform and exponential distributions. During the uniform distribution of in-service time here take place next correlations:

$$\overline{g} = \overline{n_0} = \rho + \frac{\rho^2}{2(1-\rho)} \tag{6}$$

$$\overline{t_g} = \overline{t_s}\left(1 + \frac{\rho}{2(1-\rho)}\right) = \overline{t_c} \tag{7}$$

and during the exponential distribution:

$$\overline{g} = \overline{n_c} = \rho + \frac{\rho^2}{1-\rho} = \frac{\rho}{1-\rho} \tag{8}$$

$$\overline{t_g} = \overline{t_c} = \overline{t_s}\left(1 + \frac{\rho}{1-\rho}\right) = \frac{\overline{t_s}}{1-\rho} \tag{9}$$

Most of values of factual in-service time lie between these two extreme cases. In-service times, which are equal to constant value, occur very rarely. In a real-life environment, the in-service time dispersion is not so large to consider $\sigma_{ts} = \overline{t}_s$, like it makes in an exponential law of in-service time distribution, which gives a few top-heavy sizes of queue and waiting period in it, but such a mistake is not dangerous. If we take into account that frequency distributions in a real environment are some noised in 5 - 10 %, then a little change must be made in listed above correlations.

Modeling results

The ISLS modeling results testify that near 80% service lines load the queue length during a subscriber's servicing begins catastrophically increase. In this case an insignificant traffic increase or decrease (an intensity of ingoing requirements flow) results in either to significant queues or sharp recession of a system productivity. If the service line utilization coefficient is equal ρ = 50%, then an increase of ingoing traffic to *x%* reflects in increase of queue size to $(4\overline{t}_s)$ *x%* for exponential law of distribution. If the service line utilization coefficient is equal to 90%, then an increase of queue size is equal to $(100\overline{t}_s)$ *x%*, i.e. in 25 times greater.

An insignificant increase of load with 90% service line utilization reflects in a 25-fold increase of queue size as compared with case of 50% service line utilization. Analogously changes the duration of stay in queue. With minor service line utilization coefficients the influence of σ_{ts} over patching to queue size is not significant. However, with a major ρ the over patching of σ_{ts} strongly tells on queue size. During the informational flows servicing system design it is expedient to take the service line utilization coefficient near $\rho = 0.5 - 0.7$.

References

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