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Numerical Simulation of Raw Material Stock Management

Scientific management of stocks implies the elimination of subjective and spontaneous elements.

The rhythmical implementation of the output plan is bound mainly to the manner in which the raw material supplying and stocking processes are going on. The scientific management of stocks needs stocking process substantiation on the basis of economic criteria, by using modern mathematical methods and electronic computing techniques.

As stock problems may be placed among those allowing a formulation with the aid of random variables, in order to establish an optimal management, the numerical simulation technique — more particularly the Monte-Carlo method — can be used with good results.

This paper deals with the actual application of the Monte-Carlo method to the stock management of raw materials to be used in a rolling mill producing a single assortment of rolled steel.

STOCKING PROCESS PARAMETER STUDY

Stocking processes occur in three main stages: entering the stock (supplying), stocking proper and going out from stock (consumption), characterized by time, quantitative and value (cost) parameters.

In the case under study — stocking process of raw materials in a rolling mill — the technical-economic and mathematical analysis of primary information has designated the following parameters of significant influence:

1. Supplying
— daily supplying share, L;
— supplying duration.

2. Stocking

— stock level at the moment of comsumption (rolling) beginning, NS;
— stocking cost, C_1;
— penalty cost, C_2.

3. Consumption:

— daily consumption volume, V;
— consumption duration (duration of a rolling campaign), d.

The main characteristics of the studied process are as follows:

— the supplying duration is shorter than the consumption duration (supplying sequence is faster than consumption sequence);
— the daily supply share L is smaller than consumption volume V;
— the stock movement is intermittent;
— the moment of consumption beginning is determined by the stock level;
— all time and quantitative parameters are random variables with known probability distribution:

supplying duration is determined by the probability P that an amount of the appending sort — regardless of the size of that amount — enters the stock. Consequently, the supplying duration has a binomial distribution ($P = 0.29$);

the supplying share has an exponential distribution of a mean value of 51.437 tons;

the daily consumption volume has an exponential distribution of a mean value of 137.95 tons;

the consumption duration has an exponential distribution of a mean value of 1.897 days;

costs are constant and have the values: $C_1 = 0.18$ lei/ton per day and $C_2 = 1$ leu/ton per day.

The mathematical model of the stocking process appears as a queueing model, involving arrivings of some units at irregular time intervals, a queueing line and a single station service line.

NUMERICAL SIMULATION OF STOCKING PROCESS

The stock level at the beginning of consumption (rolling) is a random variable. From the value set of this variable we suggest to select — by simulation — the value requiring a minimal stocking cost. On account of the great number of values the respective variable can get, the simulation of the corresponding variants would imply an unjustifiably high computation time. For this reason only few significant values of the stock level are settled, such as to cover all its variation range. For this purpose, one starts from the mean stock level towards bigger or smaller significant values. In the case under study the mean stock level being 685 tons, the following possible levels have been considered as significant values:

300 tons, 400 tons, 550 tons, 600 tons, 850 tons.

The simulation method consists in generating stock enterings and goings out, according to the characteristics and statistic laws of the process parameters. The block diagram of the simulation is given in Fig. 1.

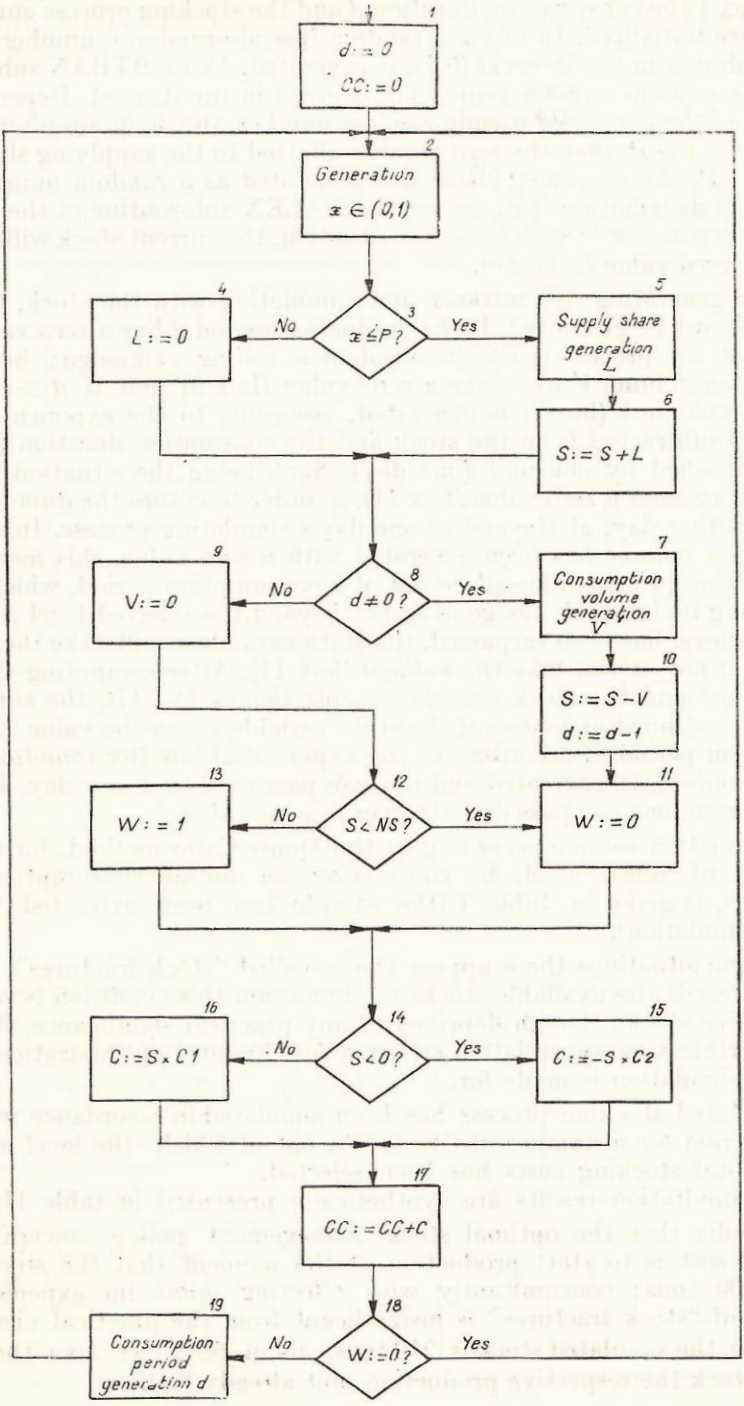

Fig.1 Simulation diagram.

In box 1 the consumption duration d and the stocking process cumulative cost CC are initialized. In box 2 a random (pseudo-random) number, uniformly distributed in the interval (0,1), is generated. (A FORTRAN sub-routine for pseudo-random number generation is given in the Annex). Depending on the value of the generated pseudo-random number, the daily supplying share is settled; if $x > P$, then the zero value is allotted to the supplying share (box 4); if $x < P$, the supplying share L is generated as a random number with exponential distribution (e.g., as per the NALEX sub-routine in the Annex). This is shown in box 5; such being the situation, the current stock will increase by the entered value L (box 6).

After generating the entrance and cumulating with the stock, the consumption must be generated. If the production period d has a zero value, this means that the process is not involved in a rolling campaign; hence the consumption volume V will have a zero value (box 9); but if $d > 0$, a consumption volume V (box 7) is generated, according to the exponential law; this one is subtracted from the stock and the consumtion duration (box 10) will be dimished by one unit (one day). Such being the situation, a state variable w assumes a zero value (box 11), in order to ensure the direct passing over to onother day, at the end of one day's simulating process. In case the consumption volume has been generated with a zero value, this means that the simulation process takes place out of a consumption period, which requires checking if the stock has gone or not beyond the selected level NS (box 12). If the level has been surpassed, the state variable w will take the value 1 (box 13); if not, it will take the value 0 (box 11). After computing the daily stocking cost and the stock cumulative cost (boxes 14—17), the simulation process is continued as follows if the state variable w has the value 1, then a consumption period d, according to the exponential law (by rounding up to a whole number), is generated and one can pass over to a new day. If w has the value zero, one can pass directly over to a new day.

A simulation sample according to the Monte-Carlo method, for a single assortment of rolled steel, by considering an initial consumption level of 400 tons, is given in table I (the sample has been extracted from a 638-day simulation).

In some situations there appear the so-called "stock fractures", i.e. the demand exceeds the available stock. In simulation this condition is reflected as a negative stock; though deprived of any practical significance, it represents neverthless an appreciation criterion for the level optimaization of the stock the simulation is made for.

The stated stocking process has been simulated in accordance with the above diagram for a number of five levels, out of which the level ensuring minimal total stocking costs has been selected.

The simultation results are synthetically presented in table II.

It results that the optimal stock management policy concerning the considered sort is to start production at the moment that the stock level exceeds 400 tons; concomitantly with effecting minimum expenses, the frequency of "stock fractures" is insignificant from the practical viewpoint. In this case, the simulated stock is 210 tons, about 50% less than the mean one-year stock the respective production unit already had.

Determining by simulation the optimal stock management for assortments with intermittent movement is a substantial aid to the operative production management and stock rationalization.

Table I

Simulation sample according to the Monte-Carlo method

(Stock level: 400 tons)

Day	Supplying share (tons)	Consumption (tons)	Stock (tons)	Daily cost (lei)	Cumulative cost (lei)
397	0	0	338	60	23,454
398	0	0	338	60	23,514
399	0	0	338	60	23,574
400	0	0	338	60	23,634
401	122	0	460	72	23,716
402	0	65	395	71	23,787
403	0	0	395	71	23,858
404	67	0	462	83	23,941
405	0	12	450	81	24,022
406	90	4	536	96	24,118
407	0	115	421	75	24,193
408	0	0	421	75	24,268
409	0	59	362	65	24,333
410	0	184	178	32	24,365
411	80	202	56	10	24,375
412	0	79	−23	23	23,498
413	0	0	−23	23	23,421
414	196	0	173	31	24,452
415	0	0	173	31	24,483
416	0	0	173	31	24,514
417	50	0	223	40	24,554
418	102	0	325	58	24,612
419	4	0	329	59	24,671
420	0	0	329	59	24,730
421	0	0	329	59	24,789
422	64	0	393	70	24,859
423	28	0	421	75	24,934

Table II

Maximum allowed level	300 t.	400 t.	550 t.	600 t.	850 t.
Number of simulated days	638	638	638	638	615
Production period frequency	48	37	27	27	28
Frequency of "stock fractures"	17	4	4	1	1
Share of "stock fractures" as against the number of production periods	35%	10%	14%	3%	3%
Total expenses	56,553	34,277	40,426	46,837	67,383

ANNEX

Generating random numbers uniformly distributed in the interval (0,1), as well as random numbers with exponential distribution of a given mean value, can be carried out by the following subroutines, written in the IBM FORTRAN IV language:

```
      SUB-ROUTINE NAUR (X)
C
C     GENERATING A PSEUDO-RANDOM NUMBER X
C     UNIFORMLY DISTRIBUTED IN THE INTERVAL (0,1)
C
      INTEGER P, Q, R
      COMMON /DD/ P, Q
C     VARIABLES P AND Q MUST BE INITIALIZED
C     IN THE MAIN PROGRAM (E.G. P = 400, Q = 401)
      IF (P .GE. 947) P = P - 947
      IF (Q .GE. 941) Q = Q - 941
      R = P + Q
      IF (R .GE. 1000) R = R - 1000
      X = R/1E3
      P = P + P
      Q = Q + Q
      RETURN
      END
```

```
      SUB-ROUTINE NALEX (M, E)
C
C     GENERATING A RANDOM NUMBER E HAVING
C     AN EXPONENTIAL DISTRIBUTION OF MEAN VALUE M
C
      REAL M,I
      I = 0,
    1 CALL NAUR(U)
      V = U
    2 CALL NAUR (W)
      IF (V .LT. W) GO TO 4
      CALL NAUR (V)
      IF (V-W) 2, 2, 3
    3 I = I + 1
      GO TO 1
    4 E = M* (U + I)
      RETURN
      END
```

REFERENCES

1. CHORAFAS, D. N.: *La simulation mathématique et ses applications.* Dunod, Paris, 1966.
2. KAUFMANN, A.: *Metode și modele ale cercetării operaționale.* Editura Științifică, București, 1967.
3. ONICESCU, O. and MIHOC, G.: *Lecții de statistică matematică.* Editura Tehnică, București, 1957.
4. ROSENSTIEHL, O. and GHOUILA-HOURI, A.: *Les choix économiques.* Dunod, Paris, 1960.

LA SIMULATION NUMERIQUE DU STOCK DE MATIERES PREMIERES

L'article présente l'application de la simulation dans le cas de la gestion des stocks de matières premières dans un laminoir, en vue de l'optimisation du stock.

Les étapes principales de la réalisation de cet objectif sont:

— l'analyse technique-économique du processus de stockage en vue de l'établissement des paramètres significatifs;

— l'analyse statistique-mathématique de ces paramètres;

— la simulation numérique, à l'aide d'un ordinateur électronique et l'optimisation du stock pour un sortiment de produits finis.

Les auteurs présentent l'organigramme de simulation et les principaux résultats obtenus.

ЧИСЛЕННОЕ СИМУЛИРОВАНИЕ ОТЧЕТНОСТИ ЗАПАСОВ СЫРЬЯ

В статье указывается применение симулирования в случае отчетности запасов сырья на прокатном стане в целях его оптимизации.

Важнейшими этапами достижения этой цели являются следующие:

— технико-экономический анализ процесса образования запасов в целях установления показательных параметров;

— статистико-математический анализ этих параметров;

— численное симулирование при помощи электронного калькулятора и оптимизация запаса какого-либо ассортимента готовой продукции.

Авторы приводят логическую схему симулирования и важнейшие полученные результаты.