MULTI-AGENT SIMULATION OF THE INDUSTRIAL REFRIGERATOR MATERIAL FLOWS

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Abstract

This paper is devoted to the development of a system multi-agent imitating model uniting set of technological processes, material flows and transport operations, allowing to reproduce and predict an industrial - marketing refrigerator condition in concrete situations of raw material and storekeeping receipt, production plans and realization depending on dynamics of external deliveries and trading organizations orders. When administrating the complex production and technical processes of the agroindustrial refrigerator in the condition of the uncertainty and risk the optimal decision-making depends on the simulation of the production moments, mean analytical description and consequent interaction of many engineering processes, financing and transport dealership. Authors of the given article have developed and have written the imitating model and the program, using the universal language Simplex 3. This simulation model allows to reproduce and forecast the production process's state and sale operations in concrete situations of the raw material delivery and the inventory management, as well as the production plan of working and sales of products against the fluctuation of the external delivery and the trading organizations' orders. At the same time it may be examined and optimized the finances by the simulation's methods within the main production and production cold store. It involves the multiform production and the queues for servicing, as well as the approval of decision-makings to minimize the costs, resources, etc. That is why the contribution of authors to the given work is great.

Keywords: Simulation, Material flows, Agroindustrial refrigerator, Optimization methods, Imitating modeling.

Presenting Author's biography

Liubov A. Sheshenina is the postgraduate student of the chair "Computer Technologies and Systems" of the Moscow State University of Applied Biotechnology; 1983 of birth. She has graduated from school and has entered the Moscow State University of Applied Biotechnology in 2000. Scientific interests: the system analysis and systems of imitating modeling. In 2005 she has graduated from the university and has entered the postgraduate courses.

1 Introduction

Methods, algorithms and program realization in universal imitating system Simplex3 (Schmidt 1996, 2001) agent-based simulation of the industrial refrigerator material flows are described.

The purpose of the given work is research and optimization of the industrial refrigerator material flows by methods of imitating modeling for revealing bottlenecks and the peak loadings and minimization of waiting time and order's realization.

Earlier such complex and ramified technological system was not exposed to the complex analysis, taking into account all time and conditional events. But using the given imitating model and the program it became possible. Now it can be introduced on the agroindustrial refrigerators and operatively manage the technological processes.

2 Imitating modeling of the industrial refrigerator material flows

The decision of the problem is achieved by imitating modeling process of the ramified system of the agroindustrial refrigerator material flows in the following situation (Fig. 1).

The flows of animals (cattle, pork, small cattle) from various suppliers and stockyards 1-4 (SkotoBaza_1-4), enter the sphere of primary processing cattle SferaRazb with the chamber of slaughter which basic production as fresh pair meat WaitPar in carcass MTushi, half- carcass MPoluTushi, cut MOtruba and by-products SopProd is gone to the sphere of secondary processing cattle Sfera Sbora and then on realization to distribution department KamHranSbit and then to the chamber for pair meat storage KH4 and the production for cooling process WaitOHL, for frosting one WaitZUM and by-product for frosting WaitSUB direct to the industrial refrigerator PrHolodilnik.

The production, entering the industrial refrigerator, forms meat locations for cooling WaitOHL2, distributed to the chamber for two-level cooling KO1, KO2 with the time T_{okKO1} and T_{okKO2} and then with the following after-cooling in KO3, and the location with meat for freezing WaitZUM2 in front of freezing chamber KZ1.

When the time of staying in the chamber for after-cooling T_{okKO3} and the time of staying in the freezing chamber T_{okKZ1} expires the production is unloaded from it and distributed to the distribution department KamHranSbit to the corresponding chambers for storage in KH1 and KH2. At the same time the production of secondary processing cattle Prod2i goes to the chamber for storage in selling sphere which have been saved up for realization in sphere of gathering Sfera Sbora in Prod1i location.

The by-products for freezing are entered the separate freezing chamber MKSub through the location WaitSUB2 and, when the time of freezing T_{okSub} and packing $T_{okUpSub}$ expires, are distributed to the chamber for frozen by-products storage KH3 through the packing chamber UpSub.

On the other hand of the model the location of the orders is being formed WaitP (automobiles) for all kinds of production stored in a refrigerator. The priority Prioritet, the time of arrival TarriveMash, weight ordered production gr_i and so on are determined for all automobiles.

The automobile is being entered a checkpoint StationP for order registration during the time Tp. Further it is entered the location before the station of the waybill extract WaitVN which is given out on StationVN during the time Tvn. After that, the automobile is stood in the location WaitM through the location WaitProm. Then it is distributed to the 1-st loading ramp R1 or 2-nd loading ramp R2.

The vehicle is served on the 1-st loading ramp, when it is empty, and on the 2-nd one, when the 1-st loading ramp is busy and the 2-nd one is empty.

The vehicle is loaded on the first or second loading ramp depending on it's carrying capacity, the kind of the ordered production and weight of the unloaded production from the chambers for storage. When the automobile is loaded completely, it leaves the model with the number registration of the served automobiles on the corresponding loading ramp.

Each chamber has a limited capacity (V_{KO1}, V_{KO2}, V_{KO3}, V_{KUboya}, V_{KZ1}, V_{KH1}, V_{KH2}, V_{KH3}, V_{KH4}, V_{Sub}, V_{UpSub}). When it is exceeded, the signal is given about it.

The criterion of work of the industrial refrigerator is the length of the location before the loading ramps WaitM and the waiting time of the automobile Tozh.

The following time and conditional events with corresponding condition variables are reproduced in model (Tab. 1):

Tab. 1 The time and conditional events with corresponding condition variables which are reproduced in model

1. The production arrival from the stockyards	The arrival time of cattle $T_{ArrGov1}$, $T_{ArrGov2}$, pork $T_{ArrSvin}$, small cattle T_{ArrBar}
2. Production loading in a slaughter chamber	There is even one order
3. Production leaving of a slaughter chamber	The ending of slaughtering time T_{okRazd}
4. Production loading in a 1-st stage chamber for	The arrival of production for

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cooling	cooling
5. Production loading in a freezing chamber	The arrival of production for frosting
6. By-product loading in a freezing chamber	The arrival of by-product for frosting
7. Production loading in the 1-st chamber for storage and its distribution on sub-chambers depending on a its kind.	The arrival of cooling production in the chamber for storage
8. Production loading in the 2-nd chamber for storage and its distribution on sub-chambers depending on a its kind.	The arrival of frozen production in the chamber for storage
9. By-product loading in the 3-rd chamber for storage and its distribution on the sub-chambers depending on a its kind.	The arrival of frozen by-product in the chamber for storage
10. Pair meat loading in the 4-th chamber for storage and its distribution on the sub-chambers depending on a its kind.	The arrival of pair meat in the chamber for storage
11. The automobile arrival to the checkpoint	The arrival time T_{ArrAvt}
12. The automobile servicing on the checkpoint	The checkpoint is free and there is even one order
13. The automobile servicing on the station of an extract of the waybill	The station of the waybill extract. Checkpoint is free and there is even one order
14. The automobile servicing on the 1-st loading ramp	The 1-st loading ramp is free and there is even one order
15. The automobile servicing on the 2-nd loading ramp	The 1-st loading ramp is busy, the 2-nd loading ramp is free and there is even one order
16. The decision of a problem of structural optimization of the technological system in sphere of disjoint with treelike flows' structure	Primary processing of bioraw material
17. The decision of a problem of structural optimization of the technological system in gathering sphere with network flows' structure	Secondary processing of bioraw material

Agroindustrial refrigerator is the ramified system of the material flows, casual cattle deliveries and trading organizations' orders for meat products.

In connection with the ramified system of material flows and casual character of trading organizations cattle and orders deliveries two primary problems are solved:

1. The development of rational industrial complex operating conditions providing balance between deliveries of raw material and trading order's realization in conditions of uncertainty and risk.
2. Structural optimization of the processing enterprise technological system material flows by the minimization of the deviation from adjusted structure of deliveries and assortment criterion.

The component-oriented imitating model of agroindustrial refrigerator (Fig. 1) is realized in the universal imitating system Simplex3, developed at the University of Passau (Germany), using the component-oriented language - Model Description Language (Simplex-MDL). The model of material flows is composed from basic MDL components (SkotoBazi_High, UboiRazd, KamHladZum_High, HranKamSbit, Expidiciya), describing the structure of interrelation between the basic components and the mobile components; sphere of disjoint SferaRazb of the industrial refrigerator PrHolodilnik and sphere of gathering SferaSbora.

The structural component of the highest level (Holod_High1) connects the basic components (SkotoBazi_High, UboiRazd, KamHladZum_High, HranKamSbit, Expidiciya).

Basic component SkotoBazi_High includes basic components of a subordinate level of hierarchy SkotoBaza_1... …, SkotoBaza_4, describing the entrance flows of cattle (beef) to the 1-st and 2-nd stockyards - WaitGov1, WaitGov2; pork to the 3-rd stockyard WaitSvin and small cattle (mutton) to the 4-th stockyard - WaitBar.

Basic component UboiRazd simulates work of the cattle slaughter shop. Production from four stockyards enter it through the locations WaitGov2.1, WaitGov2.2, etc. Output flows of carcass MTushi, half- carcass MPoluTushi, cut MOtruba and by-

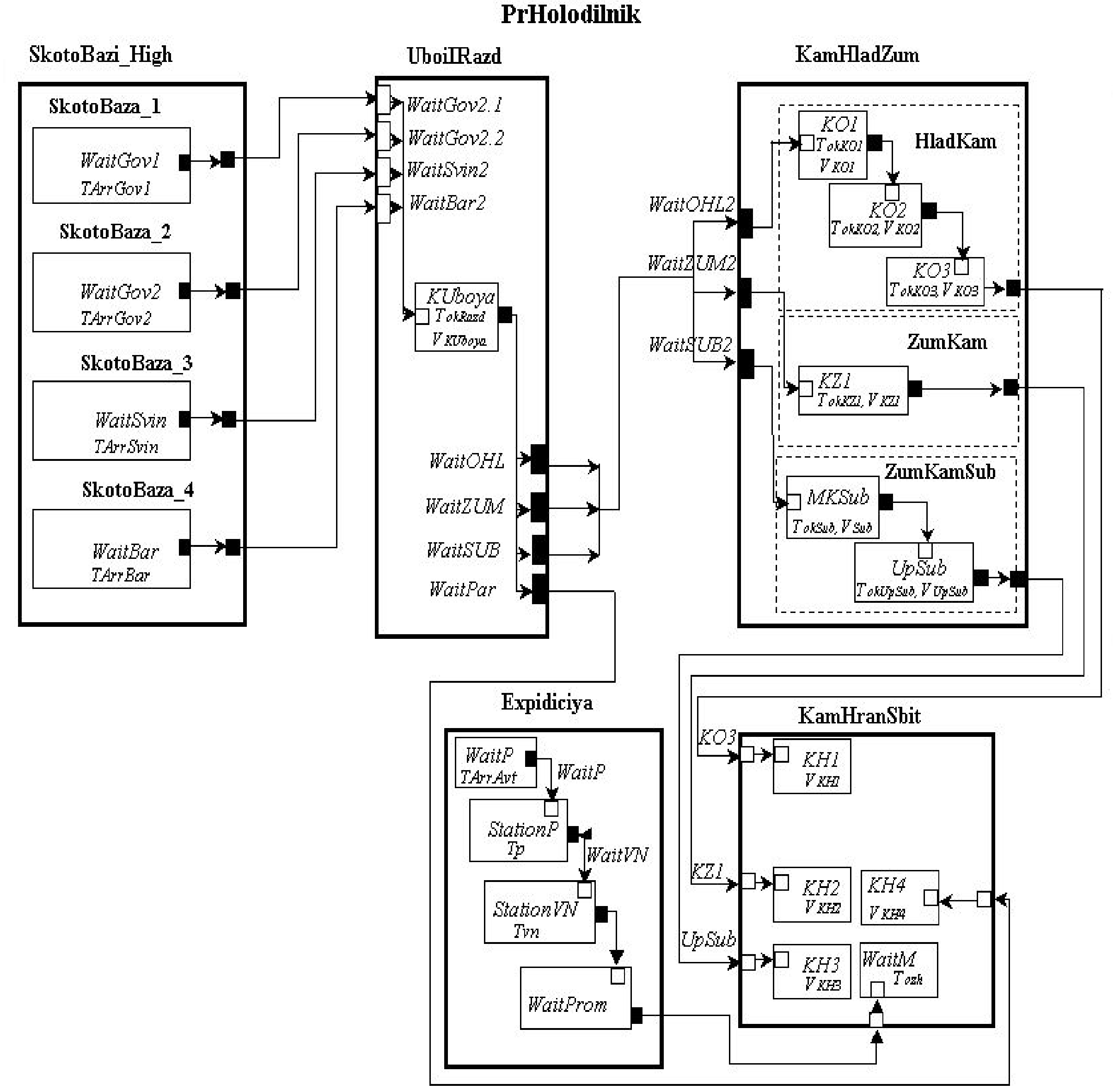

Fig. 1 The object-oriented diagram of the agroindustrial refrigerator imitating model

product SopProd, are used further for the decision of storekeeping problems and structural optimization of the technological system in in gathering sphere SferaSbora.

Basic component KamHladZum_High describes production loading / unloading to the corresponding chambers for cooling and freezing and by-product freezing. KamHladZum_High is the structural component uniting basic components HladKam, ZumKam, ZumKamSub and simulating work of chambers for cooling (HladKam), freezing (ZumKam) basic production (meat) and by-product freezing (ZumKamSub). The entrance flows of corresponding production in sphere of primary cattle processing are KO1, KZ1, MKSub. Output locations KO3, KZ2, UpSub with cooled, packed and frozen meat and by-product are directed in the corresponding chambers for storage to the distribution department KamHranSbit

Basic component KamHranSbit, simulates production loading / unloading to the corresponding chambers for the storage of the cooled / frozen meat, frozen by-product and pair meat in the locations KH1, KH2, KH3, KH4 on the one hand and the automobiles location WaitM with orders of the trading organizations for cooled, frozen meat production, by-product and pair meat on the other hand. At the same time, in basic component KamHranSbit in receiver PROD2i the production PROD from secondary processing chamber SferaSbora is collected.

The automobiles receipt and service in order WaitM before the loading ramps is described in basic component Expidiciya. The automobiles are also transferred on vehicle service from basic component Expidiciya to basic component KamHranSbit..

Basic MDL – components, which describe the conditions and dynamics of freight traffics (Fig. 1), are united in multi-agent imitating model by means of a structural component (Holod_High1) and the mobile components describing moving material flows in locations on service.

The mobile component 1 (PartiyaO) describes the material flows' characteristics of the meat cut batch, and includes priority, weight of batch mas, kind of batch vid, the contents of protein Belok, moisture Vlaga, fat Zhir, acidity pH, a kind of processing vidobrabotki, number of stockyard NumSkotoBazi, etc.

```
MOBILE COMPONENT Customer1
DECLARATION OF ELEMENTS
  STATE VARIABLES
  DISCRETE
Priority (INTEGER):=1,   #  priority
t3 (REAL) :=1,        #  interval of arrival
t4 (REAL) :=1,        #  time of arrival
mas (REAL):=1,       #  weight of  the batch of meat
vid (REAL):=1         #   kind of  the batch of meat
tobs (REAL) :=1,      # service time
mas(REAL):=1,    # weight of the production batch
vidskota(REAL):=1, # kind of the production batch
Belok(REAL):=1,     # the contents of protein
Vlaga(REAL):=1,     #  the contents of moisture
Zhir(REAL):=1,        #  the contents of fat
Azot(REAL):=1,       # the contents of nitrogen
pH(REAL):=1,                 # acidity
AktivVodi(REAL):=1,         # activity of water
vidobrabotki(REAL):=1,      # kind of processing
NumSkotoBazi(REAL):=0   # number of stockyard
END OF Customer1
```

Another mobile component describes the characteristics of vehicles, including a priority of their service Prioritet, carrying capacity Gr, arrival time TArrAvt, etc.

The grouping of basic components (SkotoBazi_High, UboiRazd, KamHladZum_High, HranKamSbit, Expidiciya) in common multi-agent imitating model is realized by means of a top level structural component (Holod_High1) by the description of links, for example (SkotoBazi_High. WaitGov1-> UboiRazd. WaitGov2.1, etc.). The material flows in the location WaitGov1 from basic component SkotoBazi_High is transferred to the basic component UboiRazd in the location WaitGov2.1.

```
HIGH LEVEL COMPONENT Holod_High1
SUBCOMPONENTS
SkotoBazi_High, UboiRazd, KamHladZum_High,
HranKamRampi, Expidiciya
COMPONENT CONNECTIONS
SkotoBazi_High.WaitGov1-->UboiRazd.WaitGov2.1;
SkotoBazi_High.WaitGov2-->UboiRazd.WaitGov2.2;
SkotoBazi_High.WaitSvin-->UboiRazd. WaitSvin2;
SkotoBazi_High. WaitBar -->UboiRazd. WaitBar2;
UboiRazd.WaitOHL--
>KamHladZum_High.WaitOHL2;
UboiRazd.WaitZUM--
>KamHladZum_High.WaitZUM2;
UboiRazd.WaitSUB--
>KamHladZum_High.WaitSUB2;
UboiRazd.WaitPar--> HranKamRampi.KH4;

KamHladZum_High.KO3-->HranKamRampi.KH1;
KamHladZum_High.KZ2-->HranKamRampi.KH2;
KamHladZum_High.UpSub-->HranKamRampi.KH3;
Expidiciya.WaitProm-->HranKamRampi.WaitM;
END OF Holod_High1
```

The dynamics of model behavior is represented as the consequent events of the receipt and the distribution of raw material flows, their processing and storage, realization and the motor transport service (Tab. 1).

3 Structural optimization of the technological system material flows

Optimization of the technological system in sphere of disjoint with treelike flows' structure and adjusted volume of bioraw material and total release production deliveries, can be carried out by redistribution of deliveries by kinds depending on production output norms, or by choice of the processing way with the most profitable production accumulation within the established limits on deliveries and release.

Mathematical formulation is realized as the minimization of the deviation from adjusted structure of assortment criterion.

$$\sum_{j=1}^{m}\sum_{i=1}^{n}\left|\frac{y_{ij}^{0}}{\sum_{j=1}^{m}\sum_{i=1}^{n}y_{ij}^{0}}-\frac{y_{ij}}{\sum_{j=1}^{m}\sum_{i=1}^{n}y_{ij}}\right|\rightarrow \min \quad (1)$$

y^0_{ij} , y_{ij} - sheduled and actual i - production release from j raw material kind;

At restrictions:

$$\sum_{j=1}^{m} G_j = G \qquad (2)$$

where G_j, G - volumes of j kind raw material resources and the general stock;

$$\sum_{j=1}^{m} \sum_{i=1}^{n_j} \mu_{ij} G_j \geq V \qquad (3)$$

V - required gross production volume in sphere of disjoint;

μ_{ij} – the i production output norm from j kind of raw material;

The problem of the gathering sphere structural optimization with network flows' structure can be carried out by solving for the optimum resource distribution of everyone j kind raw material among i technological circuits depending on the specific requirements of j raw material in i production manufacturing.

Mathematical formulation is also realized as the minimization of the deviation from adjusted structure of assortment criterion:

$$\sum_{i=1}^{n} \left| \frac{y_i^0}{\sum_{i_1=1}^{n} y_{i_1}^0} - \frac{y_i}{\sum_{i_1=1}^{n} y_{i_1}} \right| \rightarrow \min \qquad (4)$$

where y^0_i, y_i - sheduled and actual i - production release

At restrictions:

$$\sum_{i=1}^{n} y_i = V; \qquad (5)$$

$$G_j^{\min} \leq \sum_{i=1}^{n} y_i \frac{\mu_{ij}}{1-\beta_{ij}} \leq G_j^{\max}; \; j = \overline{1,m}; \qquad (6)$$

$$\sum_{j=1}^{m} \mu_{ij} = 1; \; i = \overline{1,n}; \qquad (7)$$

$$y_i^{\min} \leq y_i \leq y_i^{\max}; \; i = \overline{1,n} \qquad (8)$$

where V – the release volume of goods production;

G_j - a resource of j kind raw material;

μ_{ij} - the specific j kind raw material maintenance in i product;

βij – the coefficient of the specific j raw material losses in i product.

4 The result of modeling

The industrial refrigerator with 7000 tons capacity and following main initial data has been chosen as the research object:

- The capacity of the 1-st stage chamber for cooling - 200 tons.; holding time - 90 minutes;

- The capacity of the 2-nd stage chamber for cooling - 250 tons; holding time - 120 minutes;

- The capacity of the chamber for after- cooling - 350 tons; holding time - 420 minutes;

- The capacity of the freezing chamber - 1300 tons; holding time - 1500 minutes;

- The capacity of the freezing chamber for the by-products - 400 tons; holding time - 1440 minutes;

- The capacity of the chamber for cooled meat storage - 1200 tons;

- The capacity of the chamber for the frozen meat storage - 2700 tons;

- The capacity of the chamber for the frozen by-products storage - 600 tons;

- An automobile holding time on the checkpoint - 3 minutes;

- An automobile holding time on the station of the waybill extract - 2 minutes.

The results of modeling are represented as the protocol and as the line-diagrams of accumulation and the automobile service in the location before the 1-st and the 2-nd loading ramp (Fig. 2, Fig. 3 and Fig. 4).

On the line-diagram (Fig. 2) we can see that the vehicles is being accumulated in waiting their turn at T=592 till T=1165. The automobiles are arrived with orders for all kind of production stored in the refrigerator at 8.00-14.00. The quantity of vehicles has been remaining the same, at T=1165 till T=1987, since their arrival time was over. Then the cycle of heat treatment has finished at T=1987 and vehicles' loading and service are begun on the loading ramps. The quantity of vehicles has been remaining the same, at T=2974 till T=3425, since the time of their arrival was over. At T=10000 the quantity of automobiles in the location before the loading ramps became 162.

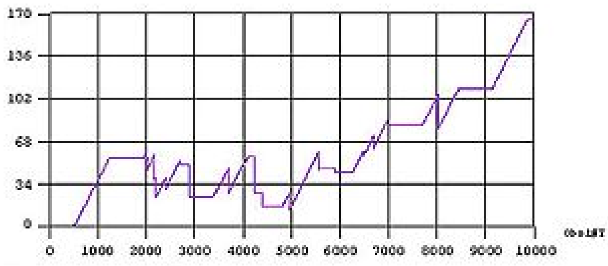

Fig. 2 The line-diagram shows the automobile's amount change in the location before the loading ramps (WaitM) depending on time

On the line-diagram (Fig. 3) is shown the production accumulation process in the corresponding chambers for storage. Reduction of production quantity is caused by its delivery on the loading ramps and servicing of automobiles with trading organizations' orders.

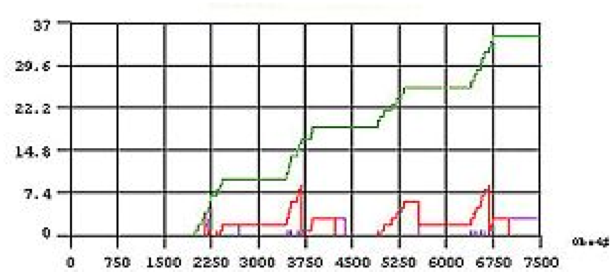

Fig. 3 The line-diagram shows the amount change of frozen mutton batch in carcasses, half- carcasses and cuts in the chambers for storage depending on time

On the line-diagram (Fig. 4) we can see that the cycle of heat treatment has finished at T=1987 and the process of automobiles loading and service on the 1-st and 2-nd loading ramps are begun. At T=1987 till T=4232 the number of the served machines on the 2-nd loading ramp exceeded their number on the 1-st loading ramp.

At T=4232 the situation has changed and further at T=5555 the number of the served machines on the 2-nd loading ramp exceeded their number on the 1-st loading ramp again.

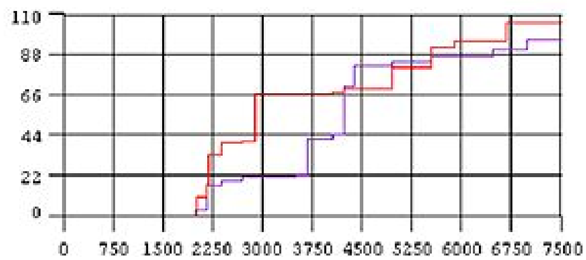

Fig. 4 The line-diagram shows the accumulation of the served automobiles amount on a 1-st and 2-nd loading ramps

The estimation of modeling results allows to detect the optimum control modes of the enterprise material flows, and to achieve rhythm in industrial refrigerator work.

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