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MANAGING INVENTORIES IN A SUPPLY CHAIN [*]

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Abstract. *This paper presents a model of inventory management within a specific production system. The theoretical basis for the given model is developed in terms of management of various conditions of real inventories in the supply chain. The model is defined as Ga which is an example of determining the inventory of real production conditions in Business Production System (BMS).*

Key words: *Inventory Control, Supply Chains, Production Planning, Genetic Algorithm*

1. INTRODUCTION

Inventories represent raw materials or half-finished goods, that is, unfinished production of the finished goods which are kept by one organization for its operative needs. As such, the inventories represent a significant investment and a potential source of the waste material which should be controlled very carefully. The process of social reproduction, viewed from the macro aspect, in most cases is not a homogeneous, continual process; and in some phases it already has disparities. Those disparities can be:

- Time (intertemporal),
- Space (interlocal),
- Qualitative, and,
- Quantitative.

Inventories, as an economic category, appear at different places in the reproduction process, at different time, different shape and different structure. Each of the shapes of the inventories aims to help us overcome the mentioned disparities. The inventories mostly manage to fulfill that task but with many oscillations in the effects. Namely, sometimes

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they are an obstacle to further process of reproduction, and in most cases they are a difficulty to that process.

Because of the previously mentioned statements, the inventories can be defined in a following way: the quantity of the raw materials, additional parts, tools, devices, -products and finished products can be considered inventories in the general case.

The function and the basic aim of the inventories is to provide for a continuous and rational run of the whole process of the social reproduction. The inventories fail to complete this task only if they are not in sufficient quantity or of proper quality in the storage. Conversely, they complete this task if present in optimal quantity and if of higher quality in the storage.

The task of the supply service is to provide for a given level of inventories, their optimal amount and their satisfying quality. So, the level of the inventories which is higher than the optimum or the one below the optimal one indirectly reflect the quality of the enterprise's business.

From the aspect of marketing, the optimal level of the inventories is easier to make with the inventories which serve as raw materials than with those of the finished products which serve directly to the consumed maturity. There is a different approach to the production of these inventories because of the problems in planning the needs. In the production process with less risk, we make the plan of the inventory needs. Along with many factors that make harder the creation of the finished product inventories, we mention several: competition, price, transport, the research of the market, the communication marketing, etc. In a market enterprise dealing only with the circulation and which does not have any additional activity (packing, marking, finishing etc.), its inventories of the goods can be considered as the finished-goods ones.

At the optimal level of inventories, among others, the type of the production and the size of the production series have a special effect, too. If the series is bigger, the price of the products is lower but the costs of the production are higher. All previously mentioned problems, and others which are not listed here, request both the professional and the scientific approach. In that sense, there are many models and methods which deal with this problem.

The aim of our interest in finding the solution to this problem is also to show one qualitative-quantitative model with which we can come to an optimal solution very easily. We took minimal overall costs of the supplies for a previously determined time interval.

2. Supply Chain Management

A **supply chain** is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer (http://en.wikipedia.org/wiki).

A supply chain consists of all parties involved, directly or indirectly in fulfilling a customer requests. Thus, the supply chain involves not only manufacturer and suppliers, but also transporters, warehouses, distributors, retailers and customers themselves (Chopra Sunil and Meindl Peter, 2007). Within each of those organizations, the supply chain includes all functions involved in researching, receiving and fulfilling a customer requests, such as (depends on type of organization and its level of development): R&D, marketing, operations, distribution, finance, customer services, etc.

Fig. 1 Supply chain
(Source: http://axtin.com, Accessed October 16th 2010)

Integral part of every supply chain is the customer. Furthermore, the primary purpose of every supply chain is to satisfy the customer's needs and to generate profit for itself. The customer is at the beginning and at the end of every supply chain.

The term supply chain may imply that only one player is involved at each stage. In reality, the manufacturer will receive material from several suppliers but he will also supply several distributors/wholesalers/retailers/customers. Thus, in reality, most of supply chains are actually networks. Because of that, it is more appropriate to use the term *supply network* or *supply web* to describe the structure of the most supply chains today (Fig. 2).

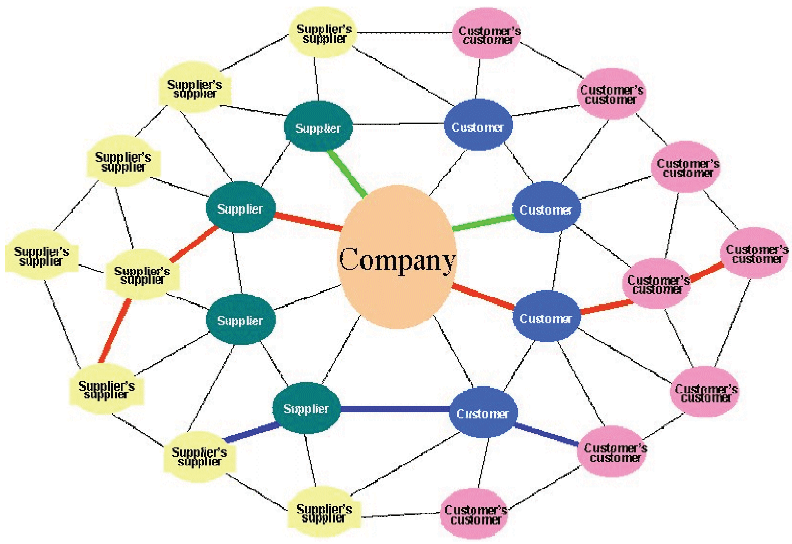

Fig. 2 Supply network or supply web
(Source: http://www.argeelogistics.com, Accessed January 20th 2011)

A typical supply chain may involve a variety of stages. Those stages are:

- Customers
- Retailers
- Wholesalers
- Manufacturers
- Component/ row materials suppliers

Each of these stages needs not to be present in every supply chain. The appropriate design of every supply chain depends both on the customer's needs and the roles played by the stages involved.

The supply chain is dynamic. In implies a constant, multi-way flow of information, products and funds, between different stages (customers, retailers, wholesalers/ distributors, manufacturers, suppliers).

The objective of every supply chain should be to maximize the overall value (supply chain surplus) generated as the difference between what the final product is worth to the customer and the costs the supply chain made in fulfilling the customer's request.

3. DECISION PHASES IN THE SUPPLY CHAIN

Chopra and Meindl (2009) stress that »successful supply chain management demands several decisions connecting to the flow of information, product and funds«. These decisions make three categories or phases, depending on the frequency of each decision and time frame in which the decisions have some effect.

Supply Chain Management has three levels of activities that different parts of the company will focus on: strategic, tactical and operational (Murray).

- **Strategic** - At this level, company management will be looking to high level strategic decisions concerning the whole organization, such as the size and location of manufacturing sites, partnerships with suppliers, products to be manufactured and sales markets,
- **Tactical** - Tactical decisions focus on adopting measures that will produce cost benefits such as using industry best practices, developing a purchasing strategy with favored suppliers, working with logistics companies to develop cost effect transportation and developing warehouse strategies to reduce the cost of storing inventory,
- **Operational** - Decisions at this level are made each day in businesses that affect how the products move along the supply chain. Operational decisions involve making schedule changes to production, purchasing agreements with suppliers, taking orders from customers and moving products in the warehouse.

Competition strategy of an enterprise defines a pack of needs which it aims to satisfy through its products and services. *The strategy of the supply chain* determines the nature of procurement of raw materials, of the transport of the material to and from the enterprise, the production of the product or the operation for giving services and distribution of the products to the buyer, together with all following services. The decisions about the inventories, transport, locations and the flow of information in the supply chain are a part of the unique strategy of the supply chain.

The strategic compatibility means that the competition strategy and the strategy of the supply chain have the same goal. That relates the consistency between the priorities of a buyer which the competition strategy is designed to fulfill and the possibilities of the supply chain which the strategy of the supply chain tends to build. There are three basic steps for achieving the strategic compatibility:

1. Understanding the Customer and Supply Chain Uncertainty. First, the enterprise must recognize the customer's needs for each goal segment. Understanding his needs helps the company to cope with variations and other problems in supply chains.
2. Understanding the Supply Chain Capabilities. There are many different types of the supply chain, and each of them is designed to do certain tasks in an effective way. The enterprise has to understand what for it designs its own supply chain.
3. Achieving Strategic Fit. If there are any incompatibilities between what the supply chain does at agreeable way and the desired customer requirements, the enterprise has to restructure the supply chain in order to support the competition strategy, or to change its own strategy.

Fig. 3. shows the finding the zone of strategic fit.

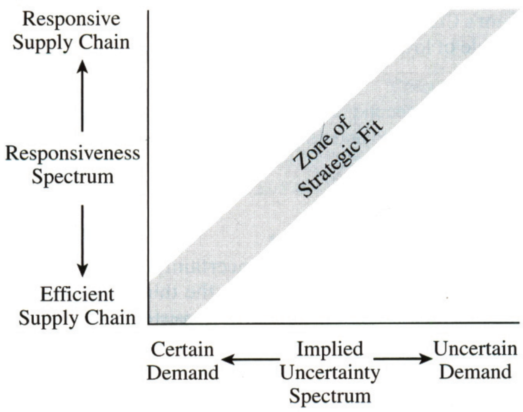

Fig. 3 Finding the zone of strategic fit (Copra, Meindl, 2009, p. 46)

The domain of strategic fit is to understand tasks of each stage of the supply chain and it is way how to fit appropriate strategy. When the domain is narrow, the individual functions focus on the optimization of their own performances based on their own goals. This kind of practice often results in conflict actions along the supply chain which lessen the overall contribution of the supply chain. As the domain of strategic compatibility is widened to the whole supply chain, the actions are based on their effect on the performances of the entire supply chain, which helps in maximizing the overall effect of the supply chain (Fig. 4).

The enterprise which has achieved the strategic compatibility found the right balance between the reactions and efficacy (Fig. 5). Each of the drivers affects the balance. A bigger number of departments, in general case, contributes to a better reaction of the supply chain, while only few central departments creates higher efficacy. The investment in the information, that is in the information system, can significantly improve the supply chain in both directions. However, at some moment the managers of the supply chain should determine whether the improvement of the benefits from the information to the supply chain could justify bigger costs of the information.

A bigger variety of the products, a shorter life cycle of the products, buyers with greater and greater requests and the global competition make the creation of the strategy or the supply chain even harder because these factors can lessen the performances of the supply chain. A bigger globalization in the supply chains and the fragmentation of the ownership in the supply chains, also make the performance of the strategy of the supply chain harder.

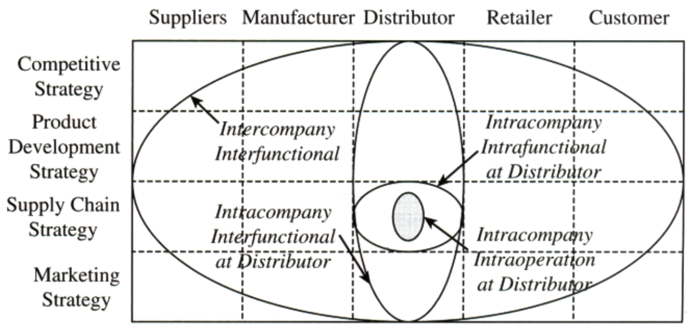

Fig. 4 Different scopes of strategic fit across a supply chain (Chopra, Meindl, 2009, p. 53)

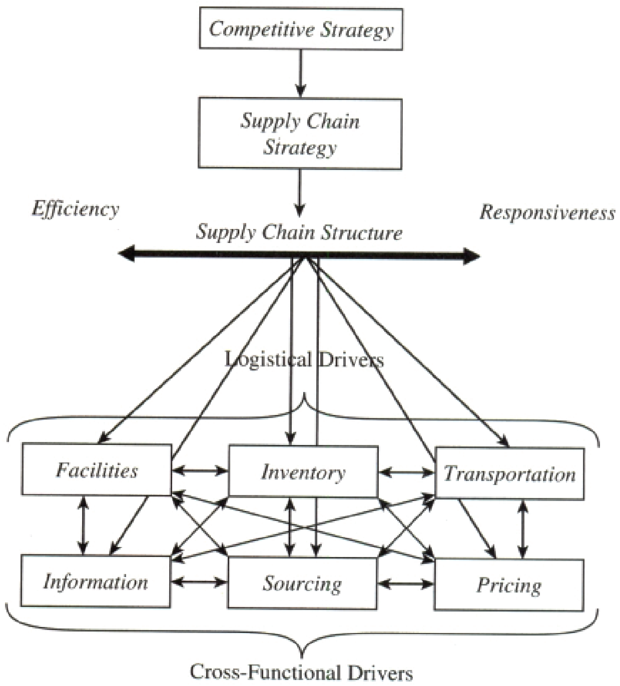

Fig. 5 Supply Chain Decision-Making Framework (Chopra, Meindl, 2009, p. 62)

4. THE MODEL OF INVENTORIES

The theoretic model of the inventories is defined in the system where the manufacturer orders raw material, and then, through the production process, changes the material into a finished product which is eventually delivered to the customer. The variable which is observed and according to which the minimal costs of the observed model are calculated is variable Q, which represents the amount ordered by the customer per one order (that is the amount which is at once distributed to the storage of the finished material in the market centre). The goal of the model is to get the optimal value of variable Q, for which the value of the overall costs of the observed supply chain is minimal (TC).

The limits of the model are: D = const; P = const.; P>D; (G) $\neq$ f(Q).

The marks used in the model are:

D – annual amount of finished products which is needed by the customer, (t/annually),
P – amount which can be produced by the manufacturer in a year time (t/annually 0,
D_r – annual need for the raw materials in the production (t/annually),
f –f = D/Dr $\leq$1, factor of the conversion of raw materials into the finished products
A – costs of customer's orders (that is, the costs if the distribution to the distribution centre),
S – costs of the production preparations of the manufacturer
G – costs of the ordering of raw materials
C_q –costs of managing the customer's inventories per one unit of the finished product, din/t
C_V – costs of managing the manufacturer's inventories per one unit of the finished product din/t,
C_R – costs of managing the manufacturer's inventories per one unit of the raw, material din/t,
r – annual capital investment in the inventories
Q – amount ordered by the customer at once, t/order
Q_M – amount produced in the production cycle, t/cycle
Q_R – amount of the ordered raw material, t/order
T_C – overall costs of the observed supply chain, din/annually

Only variable Q is observed as the decision changing, while Q_M and Q_R are tied to Q, according to relations: $Q_M = (n+1)Q$; $Q_R = kQ_M/f = k(n+1)Q/f$. Where: is the relationship between the ordered products by the customer and the amount of the products which are produced by the manufacturer. $\forall$ n = 0 is about the *just-in-time* production; $\forall$ n > 1, the manufacturer produces more finished products than ordered, so he keeps the part of it as a reserve. K is the relationship between the ordered amount of the raw materials and the amount spent by the manufacturer in the production cycle, where k equals (1,2,3,...,m) $\cup$ (1,1/2,1/3,...,1/m) and m is the whole number. $\forall$ k = 1, the amount of the ordered material equals the amount needed for one cycle of production; $\forall$ k > 1, the amount ordered is bigger than the amount needed for the production cycle so a part of the material is kept as the reserve; $\forall$ k < 1, the amount of the ordered material is less than the amount needed for the production cycle, so during the cycle there has to be an additional ordering of the goods, according to the model of urgent orders. In this way, we can consider the flexibility of the supply chain itself, because only with flexible supply chains the changes of n and m are possible, according to the market requests. According to the defined limits, we have developed the following equations of the model for different terms of business:

Case 1: (k≥1; k∈(1,2,3,4,...,m))

$$TC(m,n,Q)=\frac{D}{Q}\left(A+\frac{1}{(n+1)}S+\frac{Gf}{m(n+1)}\right)+\frac{Q}{2}r\left(C_Q+C_V\left[n\left(1-\frac{D}{P}\right)+\frac{D}{P}\right]+C_R\frac{(n+1)}{f}\left[\frac{D}{P}+(m-1)\left(1-\frac{D}{P}\right)\right]\right)$$

Case 2:

a) (k≤1; k∈ 1,1/2,1/3,1/4,...,1/m))

If the price of the supplies according to the model of urgent orders is the same as in the regular supplies, then we have the following equation:

$$TC(m,n,Q)=\frac{D}{Q}\left(A+\frac{1}{(n+1)}S+\frac{f}{(n+1)}Gm+\frac{Q}{2}r\left(C_Q+C_V\left[n\left(1-\frac{D}{P}\right)+\frac{D}{P}\right]+C_R\frac{(n+1)}{mf}\left[\frac{D}{P}\right]\right)\right)$$

b) If we consider a more real case, where the price by the model of urgent supplies is higher in comparison to the regular supplies (G_1>G), we come to the following equation:

$$TC(m,n,Q)=\frac{D}{Q}\left(A+\frac{1}{(n+1)}S+\frac{f}{(n+1)}(G+(m-1)G_1)+\frac{Q}{2}r\left(C_Q+C_V\left[n\left(1-\frac{D}{P}\right)+\frac{D}{P}\right]+C_R\frac{(n+1)}{mf}\left[\frac{D}{P}\right]\right)\right)$$

5. Inventories in Contemporary Market and Technological Conditions

The task of this paper is to define the amounts of the reproductive material kept as inventories in a contemporary way, in order to produce a product with minimal resources, so that the inventories are minimal.

In order for the planning of the inventories of reproductive material to be real and in line with the requests and tasks of the enterprise, it is necessary to constantly question and observe the market of the supplies of reproductive material. In that way the enterprise lessens the risk of the wrong orientation in the inventories of the reproductive material, as well as the planning of those reproductive material which cannot be provided in the wanted time.

The technology which should be applied is Ga with which we see and model the real system.

6. The Methodology for Solving the Optimizing Problem

One of the evolution methods which is very effective for solving these combinatory optimizing problems is genetic algorithm (GA). The advantages of the GA are:

- The objective function which should be optimized is completely average, that is, there are not any special requests such as continuity, differentiability, etc.
- It can be applied to a great number of problems of different nature;

- The structure of GA provides many possibilities of improvement and increasing the algorithm efficacy;
- The reliability of the results can be increased by simple repetition of the actions;
- The result is a pack of solutions rather than one solution.
- It solves all the problems which can be shown as optimizing, no matter if the variables are real numbers, bits or signs;
- It simply applies to multidimensional problems;
- There are finished computer packs which can be applied for the solution of concrete problems. This paper uses computer realization of GA in computer program MATLAB.

  Weak points of GA are:
- It has to be adjusted to the given limits;
- It is often necessary to adjust the problem to the algorithm;
- It has a big effect of parameters on the efficacy. There is not any universal rule for adjusting the parameters;
- The convergence is slower than other numeral methods. Because of many functions, GA is very slow.
- There is no a 100% reliability of the solution.

GA works with the population of units. Each unit is a potential solution to a given optimizing problem. The unit can be described as a pack of variable conditions the values of which are being optimized. The quality of the unit is quantified over the value of the fitness function of the function of goodness. The population of units is a pack of solutions to the given optimizing problem. One generation has the population with a certain number of units which have better or worse values of the fitness function. GA is a process which is done in sequences, by the application of three basic operations: selection, crossing and mutation. Eventually there is a new generation of the population of units (solutions). After a certain number of generations, the process GA is stopped. The best unit from the last generation represents the solution of the optimizing problem, which is usually very close to the global optimum.

The iteration of GA can be divided into two phases. At the beginning of the process there is a current population. The selection enables the elimination of bad units (solutions) and surviving of better units (with better fitness functions). In that way we create one mid-population (the pairs of parents). The selection can be understood as the formation of these pairs-parents. The next phase includes the operations of crossing and mutation. Crossing is the process which, by the exchange of the parent genes, there appear two new units-children. After that, there is the mutation process, by which the units from generation to generation become better and better, which means that the values of the variable conditions are closer to the optimal values. The structure of GA is shown in Fig. 6.

This paper uses the computer realization GA in the program pack MATLAB R2008b within the toolbox/gads module.

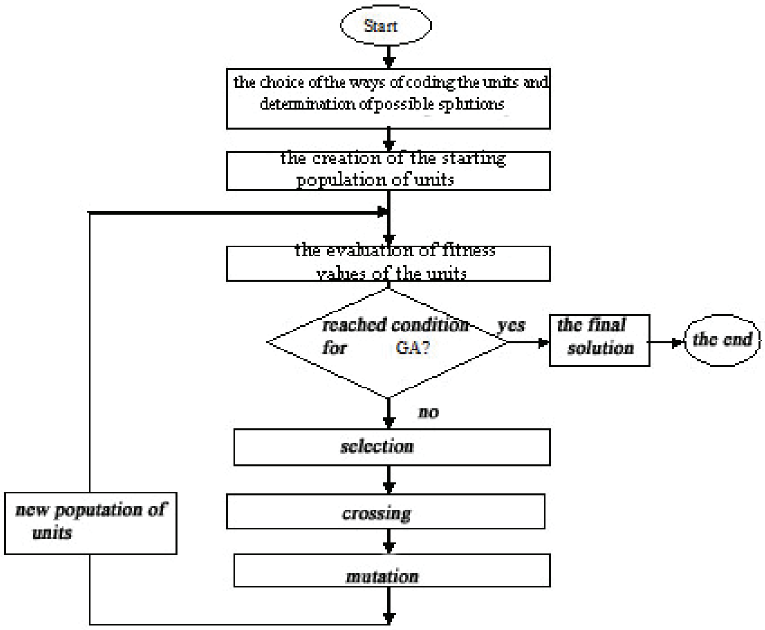

Fig. 6 The structure of genetic algorithm

7. TEST EXAMPLE

The described methodology is applied to two characteristic examples, with the following parameters:

D=1000 (t/annually); P= 1200 (t/annually); D_r =1100 (t/annually); f =0.91;
A=50000 (din/order); S=520000 (din/quartal); G=780000 (din/quartal);
C_q=130000 (din/t); C_V=130000 (din/t); C_R=130000 (din/t); r=1;

1st Case: The scopes of possible values of the variables which need optimal values are:

k=[1÷5]; n=[1÷2]; Q=[1÷1500] (t/order);

This example shows the relationship between the ordered amount of raw material and the amount which is spent by the manufacturer in the production cycle, which is higher than one or equals one which means that the amount of the ordered raw materials is higher than the amount spent in the production cycle (k.1).

The application of the described methodology brings to the optimal values of the driving variables which have minimal overall costs:

k=2.9; n=2; Q=28 (t/order);
TC= 21733000 din/annually

With achieved optimal values of the driving variables (m, n, Q), for the amount of the products per one production cycle QM and the amount of ordered raw material QR we get:

QM = 84 (t/cycle); QR=258 (t/order)

Fig. 7 gives the change of the best and average value of the fitness function during the process of GA in the process of reaching the optimal solution.

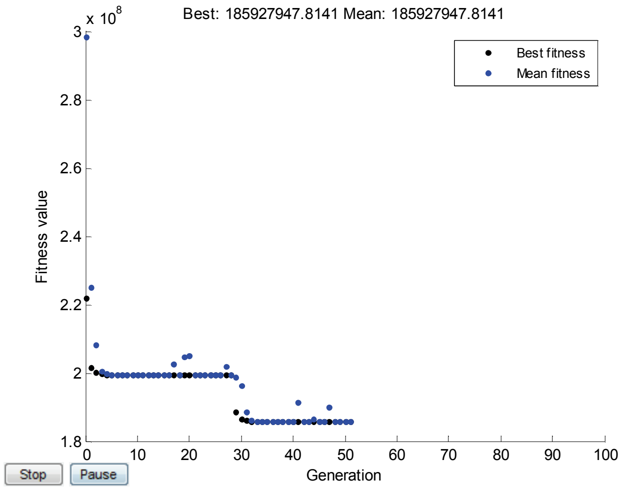

Fig. 7 Process of GA in the process of reaching the optimal solution for the example 1

The first case is that the amount of the raw material for the production is higher than the amount needed for one production cycle. In that way, a certain amount of raw material is found in the manufacturer's inventories. This way of production brings us to somewhat higher costs of storage, but not to the additional costs which are caused by the urgent orders during the production cycle itself.

2nd Case: This example shows the relationship between the amount which is spent by the manufacturer in the production cycle which is lower than one or equals one which means that the amount of ordered raw material is lower than that which is spent in the production cycle (k,1).

k=[0.1÷1]; n=[1÷2]; Q=[1÷1500] (t/order);

Now we get these results:

k=1; n=1; Q=1500 (t/order);
TC= 249490000 din/annually

With the given optimal values of driving variables (m, n, Q), for the amount of products per production cycle QM and the amount of ordered raw material QR we get:

QM = 3000 (t/cycle); QR= 3296 (t/order)

Fig. 8 gives the change of the best and average value of the fitness function during the process or genetic algorithm in the process of reaching the optimal solution for the Example 2.

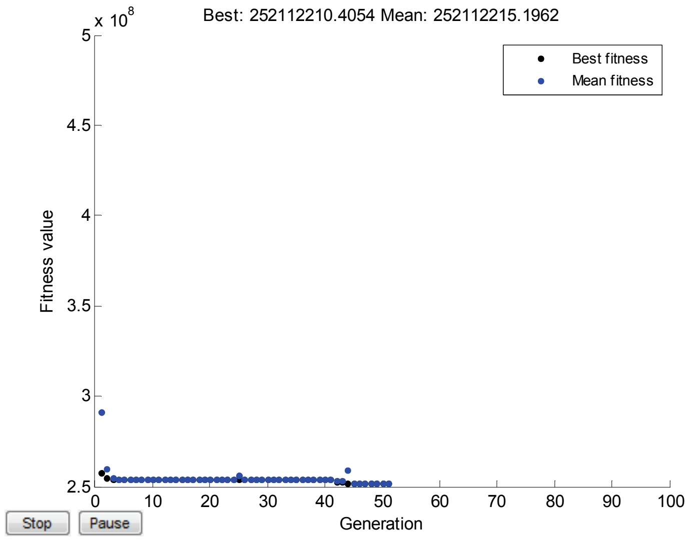

Fig. 8 Process or genetic algorithm in the process of reaching the optimal solution for Example 2

The second case deals with the model with urgent orders, but by the price of raw material equal to the price by the regular inventories. In the conditions defined by the real parameters got according to the so far business of the observed PPS, we have reached optimal value of the final product and with minimal overall costs of the observed production process.

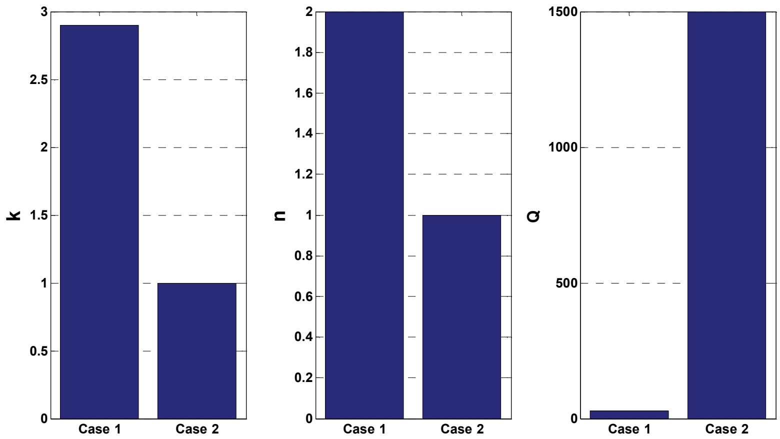

Fig. 9 Comparison of results from Examples 1 and 2

8. CONCLUSION

The existence of the inventories of raw material is unavoidable. On one hand, there are requests for the continuity of the production process, which is very sensitive with the shortage in the reproductive material, while, on the other hand, the fact is that it is practically impossible to arrange the delivery of the reproductive material and its engagement in the production process.

This paper shows the approach to the strategic management of the inventories and ordering within one real PPS.

According to the previously formed model which embraces the costs of the preparations for the production, those of ordering raw materials for the production and those of their inventories, we search for possible solutions of the observed problem of optimization of the value of production series from the aspect of two potential cases in the production practice of the enterprise. The first discussed case is when the amount of the ordered raw material is bigger than the amount needed for one production cycle. In that way, a certain amount of raw material is in the manufacturer's inventories. This way of production brings us to somewhat higher costs of storage, but there are no additional costs caused by urgent supplies during the production cycle itself. The second case refers to the model with urgent supplies, but at the price of raw material which is equal to the price in the regular supplies. In the defined conditions, we get the optimal value of the produced amount of the material and in that way minimal overall costs of the observed integrated production process.

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UPRAVLJANJE ZALIHAMA U LANCU SNABDEVANJA

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U ovom radu je predstavljen model upravljanja zalihama u okviru konkretnog proizvodnog sistema. Date su teoretske osnove modela razvijene sa aspekta različitih uslova realnog menadžmenta zalihama u okviru lanca snabdevanja. Definisan je Ga i primer određivanja zaliha na realne proizvodne uslove u jednom Poslovno Proizvodnom Sistemu (PPS)[1].

Ključne reči: *upravljanje zalihama, lanci snabdevanja, planiranje proizvodnje, genetički algoritam*