# Synergy of Process and Production Planning by Discrete Simulation in Manufacturing

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***ABSTRACT***

*The survival and growth of businesses in today's market is based on constant innovation and new product development. Business innovation must take place at all levels, from products, processes to the organization itself, in order to bring about improvements in competitiveness and business efficiency. Furthermore, the number of different components of many products, and, consequently, the demands for the appropriate manufacturing processes and operations, have also increased manifold. We can respond to such demands and manage the appropriate tools to simulate the activities and processes within the factory in the virtual world. The simulation of the entire flow of materials, including all significant activities of production, storage and transportation are key requirements for quality production planning and the necessary manufacturing processes. Discrete simulations, i.e. the applications used for running this type of simulation provide the possibility of creating different scenarios concerning cases of different production parameters, the burden of production capacities, as well as their delays and failures. A further step in the development of the simulation model is the creation of a genetic algorithm for the purpose of minimizing costs and delivery times of products.*

## 1. INTRODUCTION

*Faster innovation processes and increase in number of new products developed and successfully placed on the market presents a great challenge for most companies. The main reason is their traditionally serial, distributed, manual guidance of the process* whereby the most frequent product is unnecessary paperwork. The result of this kind of business is slow NPDI (*New Product Development and Introduction*), expensive and inflexible processes which without visualization become difficult to manage and control.

The solution to this problem is shown in the form of creating digital production as a tool of PLM (Product Lifecycle Management) business approach. Thanks to its capability to link all information about products and processes of the organization, PLM systems can significantly reduce the activity that adds no value and create a foundation for the collaboration of all departments within the organization in real time using all the necessary information about the product throughout its lifecycle [1].

## 2. PLM AS INTEGRATED APPROACH TO PRODUCTION

As an effective solution for connecting human resources, business processes and systems, product information and services is new business approach called PLM (Product Lifecycle Management). This approach enables collaborative creation, management, expansion and use of product information throughout the enterprise from initial concept to product disposal [1].

PLM is defined as a strategic business approach for effective management and use of corporate intellectual assets. PLM systems meet the need of connecting all the resources and information that arise during the lifecycle of the product [2]. PLM is a business approach that uses different business solutions to connect, create, manage, distribute and use the product information throughout the enterprise [3]. This solution supports integration of people, processes, business systems, tools, methods, technologies and data.

One of the tools of PLM systems are simulations and creation of digital production which is faster and cheaper way to plan production process. With the simulation of production and generation of all processes, digital production offers

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the possibility for optimization of the existing system. It is very difficult to mathematically describe complex processes, and for their execution a large amount of funds is required, because of that the solutions such as operations research methods are used less [4]. In such an environment simulation technology is becoming an increasingly important tool for the analysis of real processes. The text below presents a particular case for which a simulation is developed as part of this project.

## 2. CASE STUDY

Created simulation model is made in Plant Simulation, part of Siemens PLM Software that enables the creation of discrete simulation. The simulation model is designed for a virtual company that has a predefined production for a certain period. So, the company has orders from customers who expect the company to meet its obligations within certain time limits. Setting the time limits is necessary in order to calculate the required capacity of resources which are also the available resources of the company. Within this model, defined time limit of production is a period of one year.

Arriving to the company the customer orders become warranties which contain information about the type of product, quantity, number of series, order date and time of delivery. Also, for creating a simulation it is necessary to dispose with information about the technological processes of each product, processing times and set-up times. After completion of capacitive sizing and programming of all the necessary methods of material flow, the initial model was created and among others the results of the availability of production resources were obtained while working in two shifts (Figure 1, 2, 4).
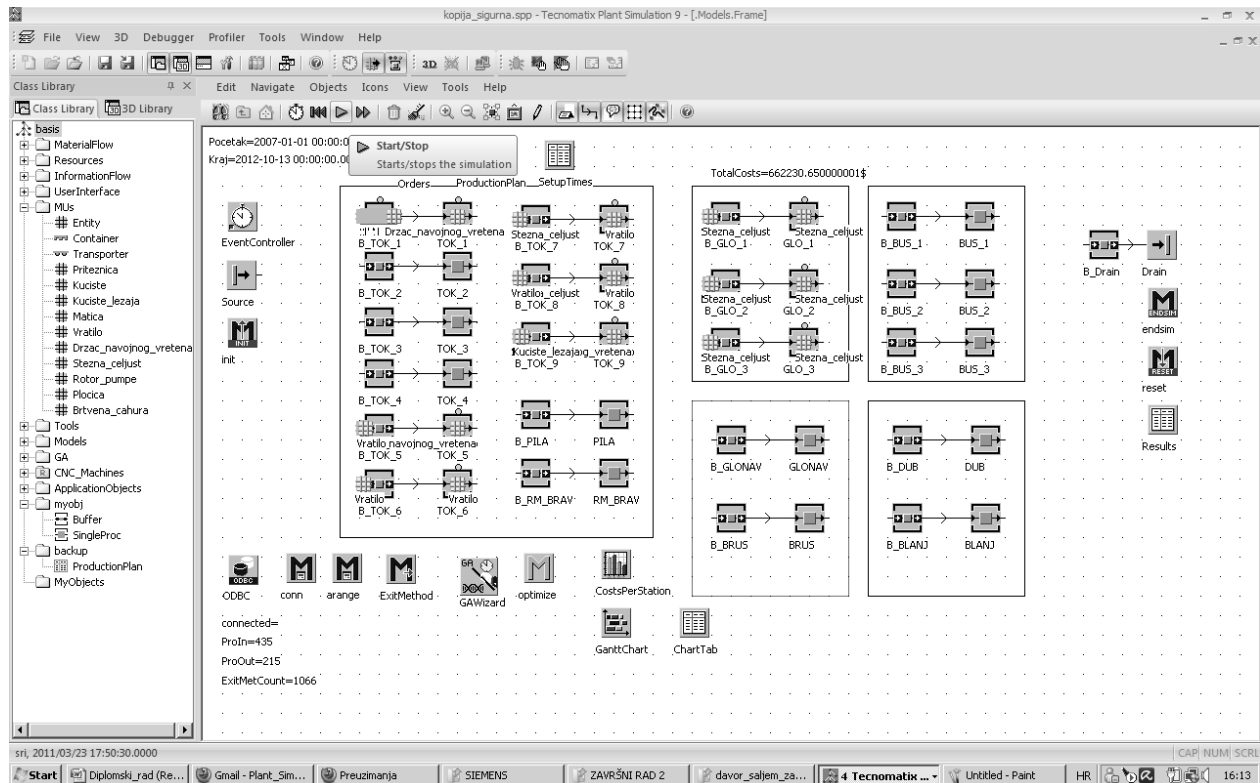


Figure 1: Initial created model in Plant Simulation

For example, for the product selected for the first operation two machine tools are available TOK_1 and TOK_2. Accordingly, a change in the *ProductionPlan* table has been made, and thus before the machine tool list is given for a particular operation, defined is the type of operation assigned to these machines, Figure [2].

Figure 3 shows improvement in disposition of machine load comparing to the model without capacitive sizing, but some machines still remain much less used.

In this model each product unit for completing one type of operation has on disposition not one but all machines on which this certain type of operation can be performed. Of course, if we define a machine as CNC, machining center or classic, the choice of the machine will affect the total cost and the total time of producing all product series. Flow of materials and machine load are presented in Figures 1, 2, 3.
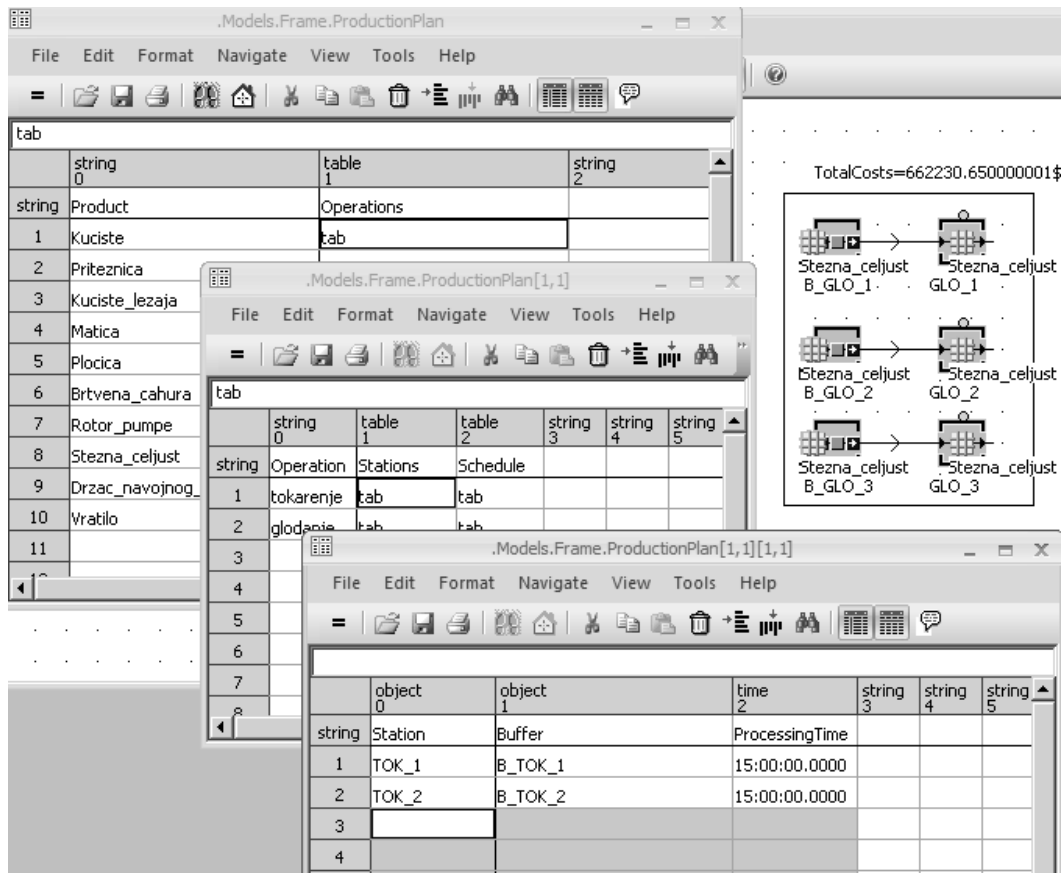
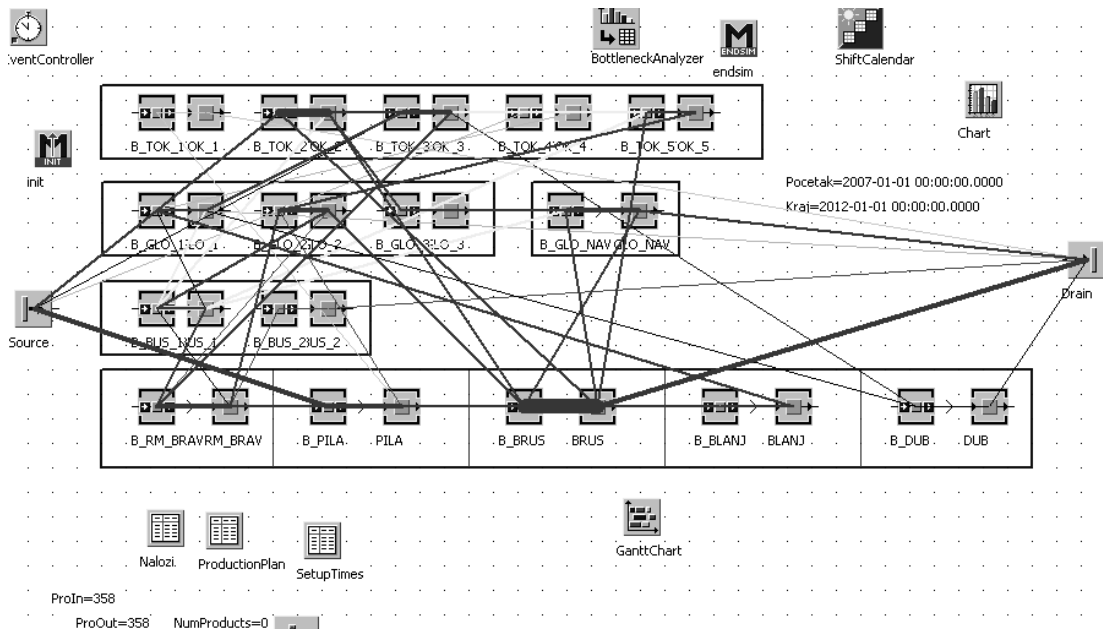Figure 2: Making tables with technological processes for developed *model*

Figure 3: Sanky diagram of material flow for initial model

Since the profit per product is in direct correlation with the cost of making products, the selection of the best variant is of great importance.
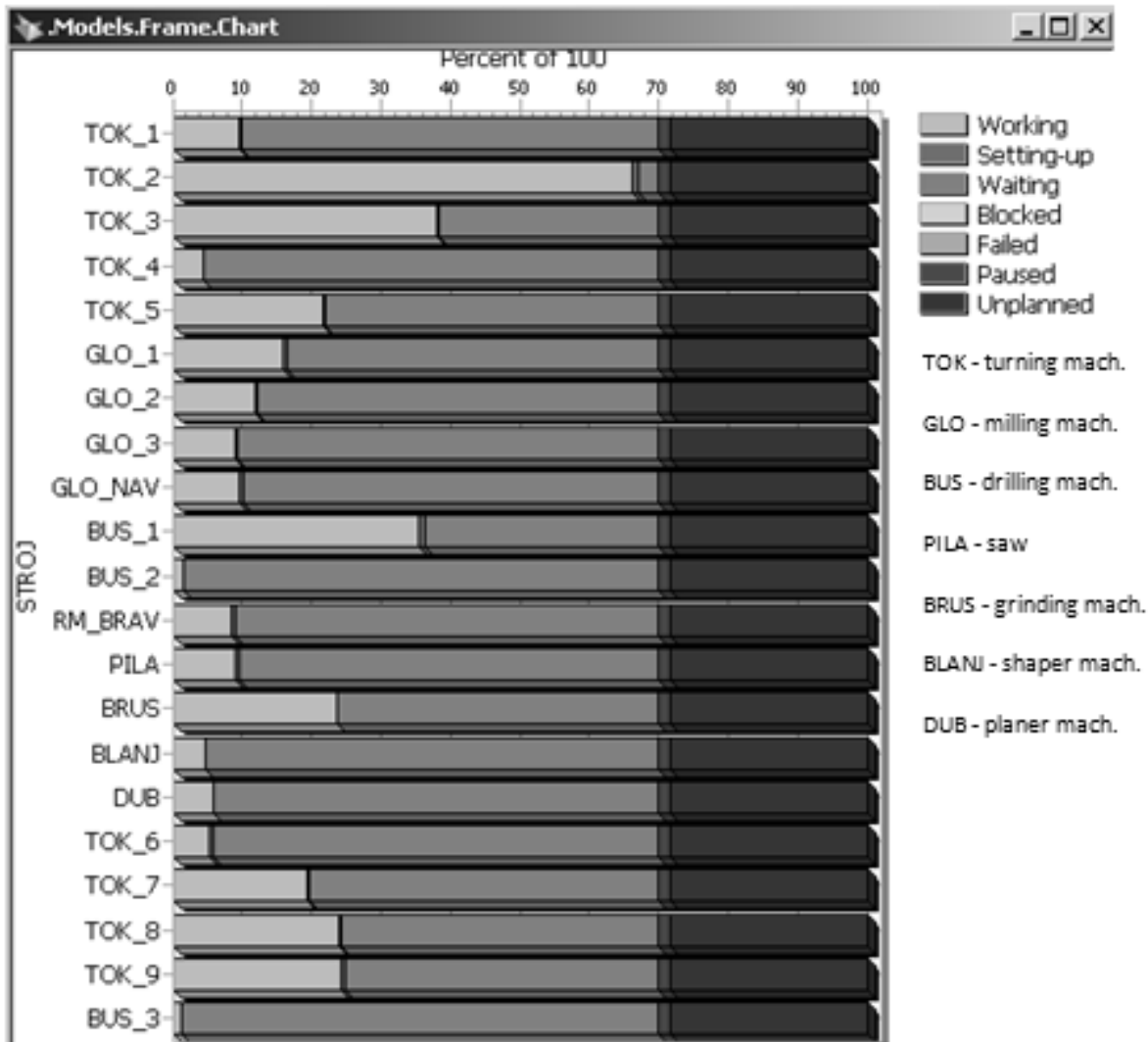


Figure 4 :The availability of machines in initial model working in two shifts

For creation of genetic algorithm in the simulation model Genetic Algorithm tool was used. Some parameters are defined through the genetic algorithm method, and some are defined in the genetic algorithm Wizard.

To use a genetic algorithm, it is necessary to define the objective function and constraints. For this model the objective function is more complex. Specifically, the aim is to produce all the products with the minimum cost, but also with the requirement to comply with the delivery date. Therefore, the algorithm is defined by a total of eleven objective functions. One of them is a requirement for the lowest cost of all products together, and the other ten are related to a request for minimum production time of each product series. Since there are several objective functions, it is necessary to determine their weight or priority factors. They are determined subjectively, where for each function  a value from 0 to 1 can be assigned.

Due to the specific input of constraints we created a new variable *Series* which measures the number of products in the series. The constraint in the algorithm represents the number of machines that are available for a particular product to execute a particular operation. So each product has a number of constraints in accordance with the following expressions (1):

$$(P1 \times K1_1 \times MK1_1 \times KP1) + (P1 \times K2_1 \times MK2_1 \times KP1) + ... + (P1 \times Km_1 \times MKm_1 \times KP2)$$

for product P1

$$(P2 \times K1_2 \times MK1_2 \times KP2) + (P2 \times K2_2 \times MK2_2 \times KP2) + ... + (P2 \times Km_2 \times MKm_2 \times KP2)$$

(1)

for product P2

$$(Pn \times K1_n \times MK1_n \times KPn) + (Pn \times K2_n \times MK2_n \times KP2) + ... + (Pn \times Km_n \times MKm_n \times KPn)$$

for product Pn

where:

$P_n$ = type of product (numerical value 1)

$Km_n$ = m-th type of operation for n-th type of product (numerical value 1)

$MKm_n$ = number of possible machines for making m-th type of operation for n-th type of

product

$KP_n$ = quantity of product,

With this a form of particular constraint can be defined, as in (2):

$$MKm_{n\text{-}min} > P_n \times Km_n \times MKm_n < MKm_{n\text{-}max}$$

(2)

Besides the constraints and objective function, it is also necessary to define the size and number of generations and the number of observations per individual. Generation represents a number of solutions that the algorithm combines, and observation represents a number of simulations for each new generated individual [5]. Thus the total number of simulations are calculated by (3):

Size of generation x (2 x Number of generations - 1) x Observations per individual.

In this model the following parameters are set:

*Size of generation = 25*

*Number of generations = 12*

*Observations per individual = 2*

Hereby the genetic algorithm is defined, and the results are shown in the following section.

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## 3. ANALYSIS OF RESULTS

With the same working conditions (working hour cost, machine availability, processing time per part) the developed genetic algorithm demonstrated very good results and in correlation with the unoptimized model. Total processing time for all products in one year production has been reduced by 28 days and the reduction of production cost was in total $ 18000 (Figure 5).
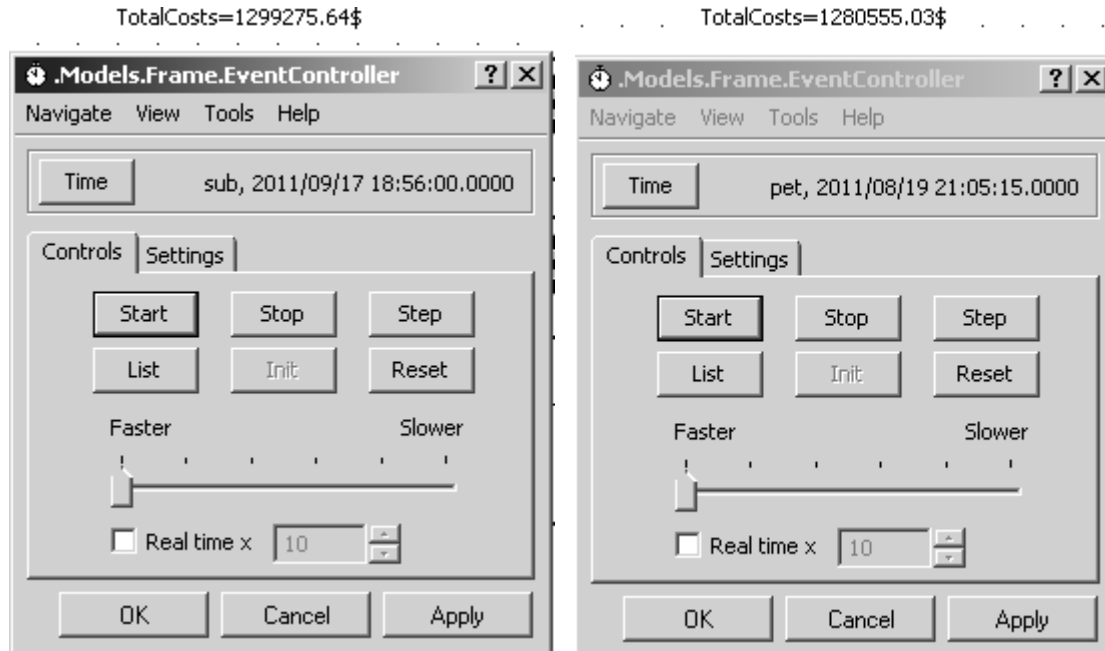


Figure 5: Result comparison of two developed simulation models

Total savings in money are even greater since the optimized model finishes with production almost one month earlier, and in real continuous systems new processes could start earlier, bringing new profit per product. Because of this, the total costs of the optimized system should be diminished for a money value that system is able to produce in time of 28 days. With this, the costs of production for the optimized model are reduced and profit per product is increased.

Figure 6 showes how the numerical value that describes the quality of obtained solution changed per generation. The results of simulations deviated from the optimal result through the first three generations. With the increased number of generations the quality of results also improved.

Genetic algorithm in total generates 570 individuals through 12 generations, and with 2 observations per individual runs in total 1140 simulations (computing time is 20 minutes). The best individual is generated in the last (12th) generation and the first observation. Also, the best fitness function of all simulations is 128755698.521. Figure 7 shows the structure of total costs per machine in the optimized model.

## 4. CONCLUSION

This project showed the idea of using simulations as a tool for production planning that allows user to optimize the results of existing systems. Although the simulation model has been made for a possible scenario of production, all input values are obtained from real observed processes and so the model is usable in real production systems for tactical and strategic planning. Simulation displayed differnet behavior of system according to variable production data (as variations of machines, different cost production per machine, different availability of machines, variable delivery times and working shifts). Also, visualization helped identifying, understanding, and connecting new information with constant changes within the manufacturing processes of one organization. Creating SQL database for the crated model and connecting it with internet technologies increased the flow rate of information. As the most important task to optimize the system, a genetic algorithm was developed and it showed very good results and improvement in the production system regarding production costs. Comparing to the unoptimized model, the production costs were

reduced for 3% of the annual turnover and the production time for all products in –one year was 28 days less. The project achieved all conditions for further evaluation in real environment.
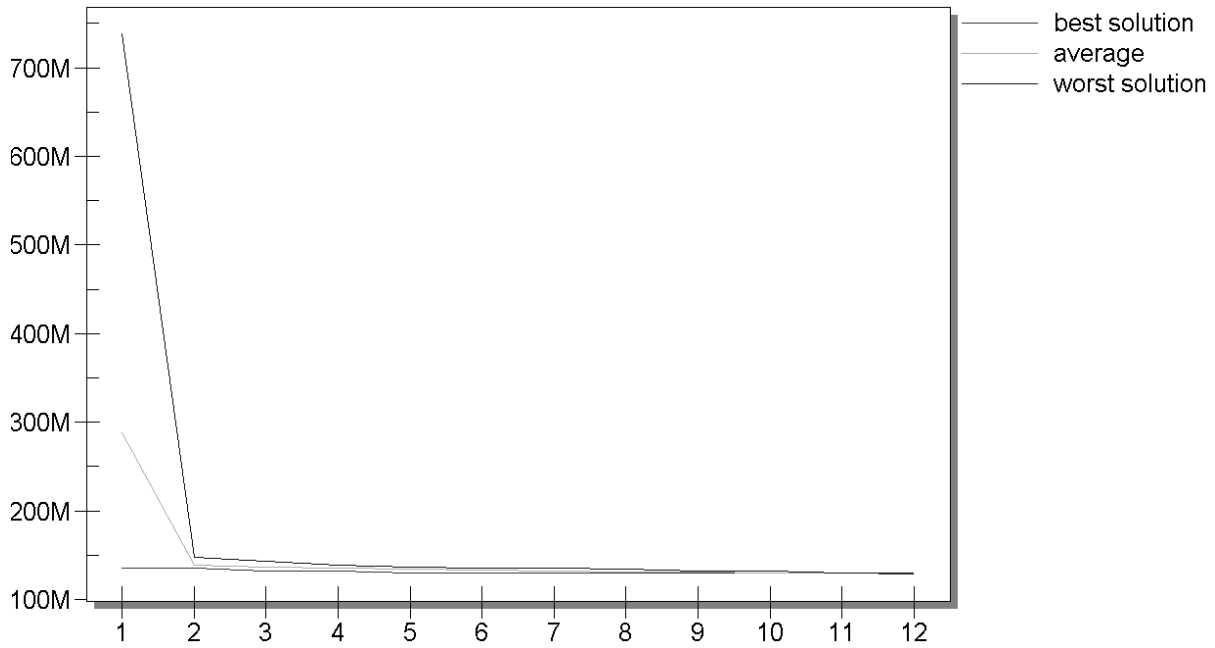


Figure 6 : The change of fitness function value through 12 generations
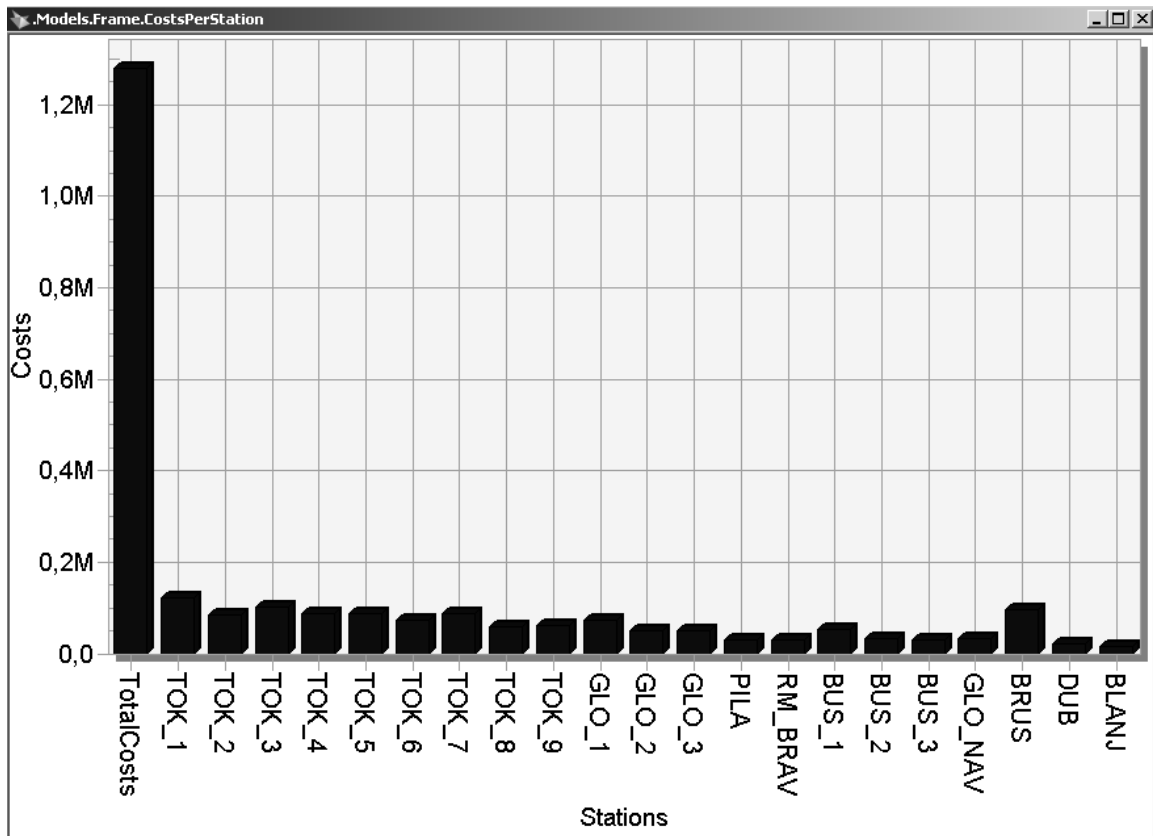


Figure 7: Structure of costs

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