MODEL STRUCTURE AND OPERATION OF A SIMULATION PROCESS SUPPORTING ELEMENT SUPPLYING OF ASSEMBLING CELLS OF MECHATRONIC PRODUCTS

Péter Telek, József Cselényi

University of Miskolc, Department of Materials Handling and Logistics

Abstract: In this paper we give a short overview about the simulation process of assembling cells. At first we draw the theoretical elements of the simulation process of assembling cells, covering important tasks, control strategies, target functions and a general module system. Second part of the paper contains the realization of this theoretical method in a software. At the end we show some screenshot about operation and results of the software.

Keywords: Logistics, supplying, stocking, assembling, simulation

Operation of assembling cells can not be usually designed by deterministic methods because of the characterisation of the assembling processes. In most of the cases the supplying processes have to be designed based on historic or prognostic data. For this purpose real processes can be described by different distribution functions which can be analysed and optimised applying simulation methods. Main purpose of our research was to develop a theoretical method (and a computer software to realize it in the practice) which can help to optimize the complex supplying tasks of the assembling processes. This paper contains the general simulation method and the operation of the developed computer software.

1. Theoretical principles of simulation analysis of assembling cells

Before describing the computer model it has to be defined the theoretical principles of the assembling process. To build the structure of the simulation model next questions have to be answered:

- which phase of the element supplying has to be supported,
- which tasks can be solved by the simulation process,
- which operation strategies have to be used in the simulation process,
- which target functions are usable for our purposes,
- what kind of modules will be the part of the simulation process.

1.1. The analysed phase

Important question before building the simulation process is the analysed phase of the element supplying, at which we have the next alternatives:

- design, previous scheduling (for terms with a duration from 3 months to 2 weeks),

- fine scheduling (for one day or one shift),
- operative control (within a day or a shift, for one- or two-hour terms),
- post-control (based on the historic data of a previous term and gives information for strategic decisions).

Depend on the selected element supplying phase, the simulation process requires different data types and processing method.

1.2. Tasks to solve

Taking the target functions into consideration the necessary tasks to solve are possible to list as below:

- to schedule the assembling process in the cells,
- to calculate the capacity requirement of workplace storages in the cells,
- to calculate the element stock levels of workplace storages,
- to calculate the capacity requirement of workplace storages and balancing stores,
- to calculate the capacity requirement of workplace storages and balancing store integrated to the given workplace storages,
- to calculate the element stock levels of workplace storages and balancing store integrated to the given workplace storages,
- to schedule the uploading process of element stock levels of workplace storages,
- to schedule the uploading process of element stock levels of workplace storages and balancing stores,
- to calculate the device and human resource requirement to supply the workplace storages,
- to calculate the optimal stock level of the main element store and the uploading periods to supply cells.

In most of the cases simulation process has to be based only on historic data which can be added by good (or not so good) prognosis or plans to modify the production. Taking this information into consideration the data structure applied for the simulation has to be defined. These data can be:

- data generated by distribution functions based on historic assembling information of a previous term,
- given data for a designed term ν broken up by Δt steps:
    - fitted to production determined by product orders,
    - fitted to distribution determined by product orders,
- product data for a designed term ν broken up by Δt steps:
    - determined once before the term ν,
    - corrected in regular periods (e.g.: daily, weekly) related to term ν.

1.3. Control strategies

Operation strategies have to be defined by the control process of the assembling. At all simulation process (for design and also control model) has to be operated in accordance to these strategies. Operation varieties of the simulation processes are also usable to analyse the effects of the chosen control strategies and select the optimal variety from the analysed ones. Control strategies have to answer the next questions:

- Element stock level of the workplace stores which can be calculated

    - by kanban-supply method uploaded to
        - constant level,
        - varying level,
    - based on the consumption of the elements uploaded in
        - one step,
        - more steps.
- Uploading terms of the workplace stores by kanban-supply method can be
    - in varying periods, uploading process started after a minimal stock level reached, with constant quantity,
    - in constant periods, uploading quantity depend on the stock level.
    - Important question that correction of the uploading term or the uploading quantity (during the production process) is
        - not required,
        - required.
- Handling of the overfilled elements of the workplace stores at the end of the scheduling term:
    - transportation back into the main element store is required if
        - the elements in the next term are not required,
        - the elements in the next term are required but the quantity for the next period has already been prepared,
    - elements stay in the workplace store if
        - the elements in the next term are required and the preparation of the next quantity can be modified,
        - the elements in the next term are not required but the workplace store capacity is large enough to store them until using in a later term.
- Determination of the quantity of the production series which can be
    - in one term only one series can be produced from a given product type,
    - from each product type one series per order,
    - certain series can be merged,
    - series have a minimal and a maximal quantity for every product.
- Determination of the order of the production series (production scheduling) which can be
    - at previous scheduling (design) of the product orders:
        - in the order of the distribution,
        - fitted to an efficient series quantity,
        - fitted to the capacity limits,
    - at previous scheduling (design) of the production:
        - scheduling not cover production details within a day or a shift,
        - important condition that the required quantity of element for the production have to be available,
        - if the scheduling can be corrected during the realization
            - it has to be repeated in every Δx term,
            - changing of the assembled quantity has to be analyzed,
        - uploading of the main element store can be evaluated by the tend of the consumption,
    - at fine scheduling of the production:
        - scheduling covers production details within a day or a shift, where the next conditions have to be taken into consideration:
            - fit to the scheduling of finished product distribution,

        - check the available quantity of the element required by the actual production term,
        - if the product can not be produced within the actual term, that applied priority of the modification has to be worked out which cause the minimal negative effects to the production process,
      - if the production plan of a product has been already modified because of the shortage of production capacity, further modification is not possible.
- Transportation strategies of the elements between the main element store and the assembling cells can happen
  - by train destination:
    - one cell,
    - more cells,
  - by partition of the required quantity:
    - all in one train,
    - parts in more train,
  - by train content:
    - train contains one kind of element,
    - train contains more types of element,
  - direct transportation, where train building methods and starting times have to be determined.

1.4. Target functions of the simulation

Before drawing the algorithm of the simulation, parameters have to be defined to qualify the analysed process. Because the determination process of these parameters can be very different, important to select them at first. Target functions can be

- minimal capacity requirement and stock level for the element stores of the workplaces,
- minimal transport requirement,
- minimal storing cost (time) of finished products,
- maximal productivity in the cells,
- minimal assembling cost,
- minimal transit time for the products.

At the selection of the target functions restrictive conditions have to be taken into consideration which can be different at the individual model varieties. For the optimization process Pareto-programming has to be applied which generally requires numeric solving process.

1.5. General module-system of the simulation process

As the element supply process of assembling cells is a highly complex task so the algorithm of the simulation has to be also complicated. Because of it the best solution to build the simulation model is using individual modules which give possibility to operate the modules separately. Suited to the main purpose of the task, two main modules have to be created which are

- previous scheduling of the cells,
- fine scheduling of the cells.

Further sub-modules related to the previous scheduling:

- calculation of the stock level of workplace storages for every element,
- calculation of the storing capacity requirement of workplace storages,
- calculation of the transport device and human resource requirement for the element supply,
- calculation of the quantities, calling and arriving date of uploading for the main element store.

Further sub-modules related to the fine scheduling:

- calculation of the stock levels and uploading times for workplace element stores,
- scheduling of the supply and return process of the elements between the main element store and the workplace storages, and calculation of the logistic resource requirement.

Further additional modules related to the general operation of the software:

- calculation of the values of the target functions,
- animation of the system,
- qualification of the results of the target functions,
- optimization of the system parameters.

If an element is used for more than one cell, then the task requires to take all of the cells into consideration for the analysis in which the given element is appearing. In this case further modules have to be applied in the simulation process.

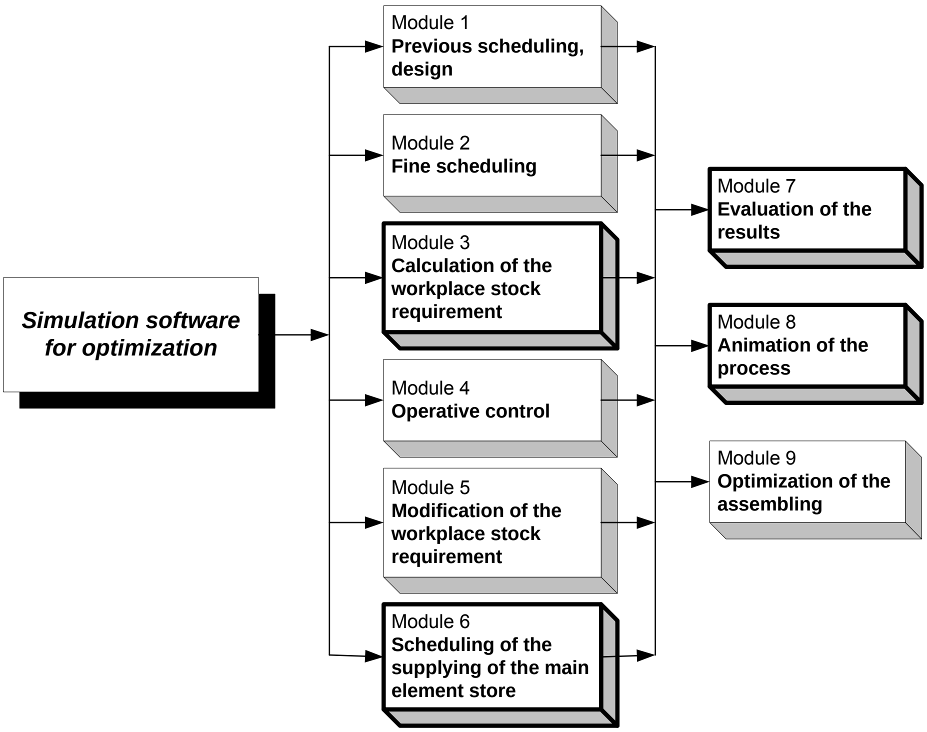

Figure 1. Module system of the simulation process
(Thick frames show the finished modules.)

Based on the above mentioned theoretical principles a general module system was described (Figure 1.) which fitted to the complex system of the operation of the assembling cells and contains the required structure for effective analysis and optimization of the element supplying processes.

2. Operation of the simulation software

Without the complete module system the optimization of the whole supplying process is not possible, but combinations of the finished modules give us devices to make different analysis at the assembling processes.
In this phase of the research a reduced simulation system was analysed which contains only the module 3, 6, 7 and 8. Because of it the reduced software is usable only for the control of the assembling programs. Finished modules can be applied for analysing the previous and fine scheduling data which can be

- imported from other software,
- processed from a previous term (historic) or a next term (prognosis),
- generated as an arbitrary production plan.

Simulation software serves to analyse the operation of one assembling cell, where product structure is known. Modifying the parameters, the software can be applicable for any of the cells, but only one cell can be analysed at the same time. If more than one cell have to be analysed at the same time, we have to run the simulation on all of the individual cells and then the results are to sum up in an other software. During the operation of the simulation the capacities of stores are constant so they have no limit. The software gives possibility to compare the running results of the different stock levels and by the help of it operation of the cells can be optimized. The actual building of the simulation process is applicable for

- analysis of determined or arbitrary generated production series,
- comparison of stock levels and simulation results of workplace storages,
- comparison of uploading parameters and simulation results of workplace storages,
- comparison of stock levels and simulation results of the main element store,
- calculation of the human resource requirement for the uploading process of workplace storages of a given cell (naturally this information is not complete, because the human resources required by different cells in the same time have to be totalized).

In the actual phase simulation let us take the next simplifications into account in the aspect of the control strategies:

- only workplace storages used in the process (no balancing store),
- required elements are in stock in the aspect of previous scheduling,
- there can be shortage of element in the aspect of fine scheduling.

2.1. Operation algorithm of the simulation process

Main steps of the simulation process (Figure 2.):

- realization of the preparation process of the actual series,
- actualization of the assembling,
- actualization of the stock level of the workplace storages,
- actualization of the stock level of the main element store,
- change fixing.

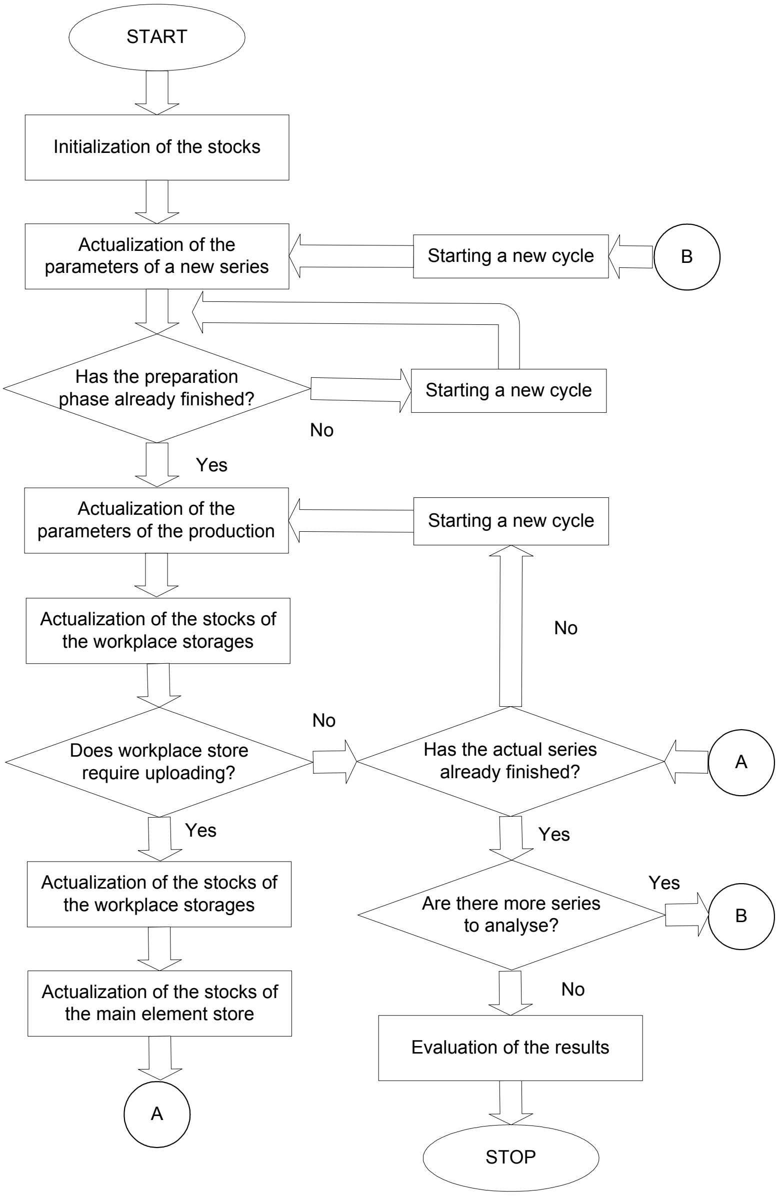

Figure 2. Algorithm of the control simulation process

The steps are running in every simulation turn, but the real activities will only be actualized, if the described conditions are exists. Times required by the physical process elements are calculated for all of the steps.

Constant input parameters of the simulation process:

- number of assembled product types,
- period of the analysed term,
- schedule of the simulation process,
- quantity of the given product types during the term,
- element types required by each product type,

- quantity of elements required by one product,
- assembling time of one product,
- preparation time of product series,
- loading units of the elements,
- quantity of the elements in one loading unit,
- uploading time of the elements between main element store and the workplace storages,
- average series size of the assembled product types,
- typical series size of the assembled product types,
- element stock size
  - in the workplace storages,
  - in the main element store.

Beside the above mentioned parameters, characterisation of production series are also defined:

- parameters of each series,
- number of the series by each product type,
- production-series-size by each product type,
- production order of the series.

2.2. Presentation of the results of the software

The software, created to realize the theoretical model of the simulation process, makes three different parameter set which are shown in diagrams in separated windows. Results can be created on all elements and contain the next information:

- data of element stock of workplace storages,
- data of element stock of the main element store,
- data of uploading process of workplace storages.

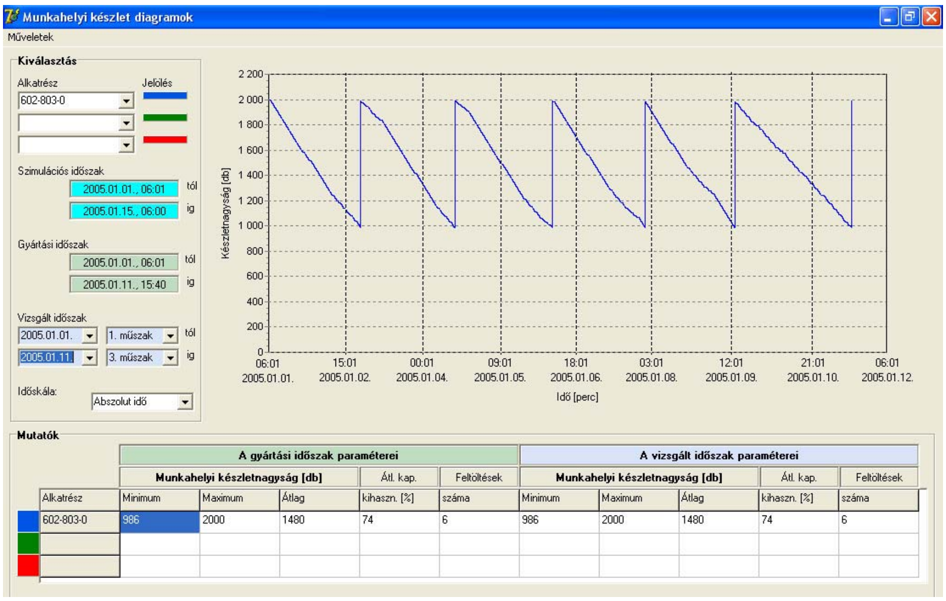

Figure 3. Window to present the workplace stock

Figure 3. shows the diagram of the element stock of workplace storages, which gives information about stock changing of time. By the help of this diagram space requirement of the storages can be determined. Screenshot on the picture consists of continuous element supplying.

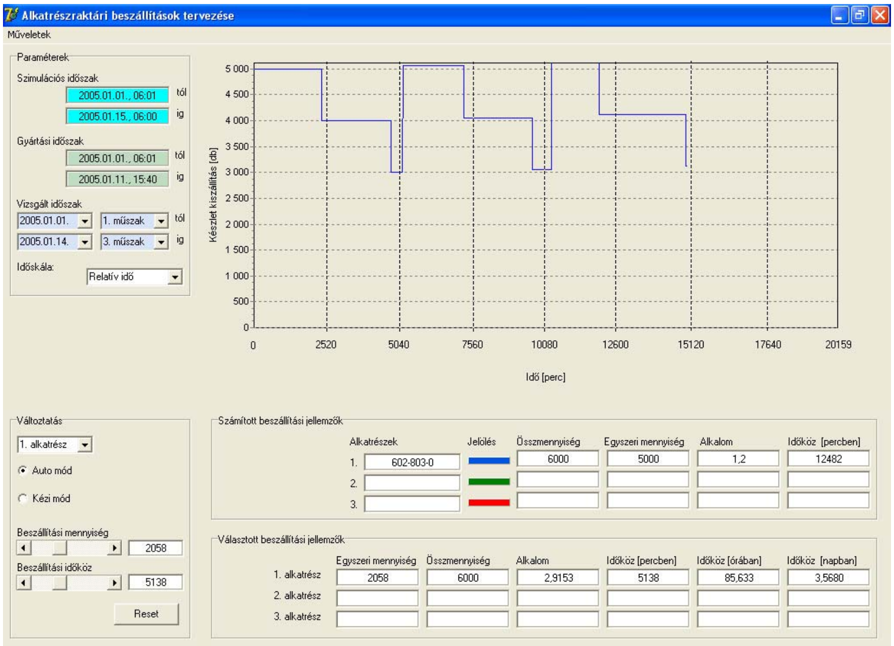

Figure 4. Window to present the stock of the main element store

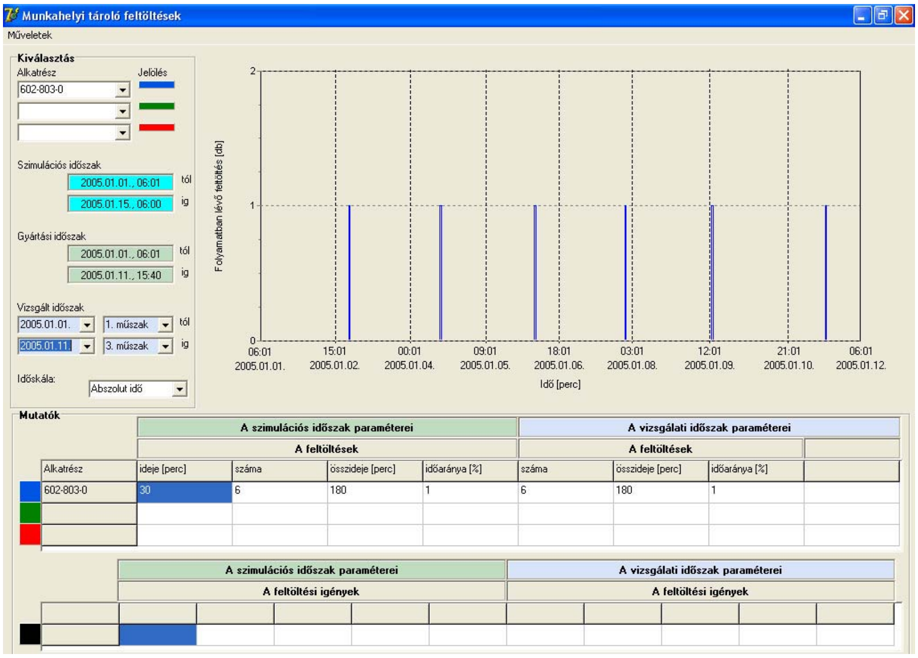

Figure 5. Window to present the uploading process of an element

Figure 4. shows the diagram of the stock of the main element store, which gives information about stock changing of time and the uploading of the element. By the help of this diagram space requirement of the stores can be determined and effects of varieties of supplying quantities and terms can also be analysed. Screenshot on the picture consists of discrete element supplying, different partitions of the diagram are determined by the uploading processes (discrete quantities – fitted to the kanban-box) of the workplace element stores.
Figure 5. shows the diagram of the uploading processes of workplace stores, which gives information about the uploading process of time. By the help of this diagram logistic resource requirement (quantity and performance) of the assembling process can be determined.
Important question at the uploading process of the workplace stores the determination of the total resource requirement during the assembling process. To analyse this parameter software gives an other possibility to show the totalized diagram of the uploading process. In addition the software offer possibility to zoom the necessary details of the process.
At this time, the finished parts of the simulation method (and of course the software to realize it) stand in industrial test, this application can increase the efficiency of the serving process of the assembling processes.

3. Summarize

In advanced technology assembling processes are actualized on assembling cells (lines), where the individual cells are built to produce only one product type, or group (of similar products) efficiently.
In this phase of our research the target was to develop a method, and a computer software to realize it, which can analyse production plans of assembling processes and determine the required element supplying tasks.
The module system of the general simulation process lets new module elements add to the process which cover more parameters to analyse. Developing module 1 (Previous scheduling) and 9 (Optimization) solvable tasks can be extended

- to optimize the assembling process,
- to optimize the stocks of workplace storages,
- to optimize uploading process of workplace storages,
- to optimize the stocks of the main element store.

References

[1] KLAUS BRANKAMP: **Gyártási és szerelési kézikönyv**, Műszaki Könyvkiadó, Budapest 1980.

[2] NÉMETH TIBOR: **Gépipari szerelés**, Műszaki Könyvkiadó, Budapest 1981.

[3] DR. CSELÉNYI J. – DR. ILLÉS B. (szerk.): **Logisztikai rendszerek I.,** Miskolci Egyetemi Kiadó, 2004.

[4] CSELÉNYI JÓZSEF, TELEK PÉTER: **Mechatronikai termékek szerelésére alkalmas munkahelyek alkatrészellátási stratégiájának szimulációs vizsgálata** Innováció és tudás, MLR-RET Konferencia kiadvány, ISBN 963 661 691 4, pp.: 159-174. Miskolci Egyetem, 2005.

[5] DR. CSELÉNYI J. – DR. ILLÉS B. (szerk.): **Anyagmozgatás-logisztika. Tudomány a gyakorlatban**. Horizont Média Kft., Kiskunhalas, 2006. ISBN 963 06 0848 0

[6] DR. CSELÉNYI J. – DR. ILLÉS B. (szerk.): **Anyagáramlási rendszerek tervezése I.**, Miskolci Egyetemi Kiadó, 2006. ISBN 963 661 672 8