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Simulation Modelling of Manufacturing Business Systems

Nenad Perši
University of Zagreb, Faculty of informatics and organization Varaždin
Croatia

1. Introduction

Due to their intense dynamics, business environment relationships in the market drive constant changes within business systems and continuous accommodation to the newly arisen circumstances. As business operations have become too complex and dynamic, adaptability has arisen as one of the major features of business systems. A possible solution to the problem of increased flexibility and the ability for quick adaptation is the development of a business system states model as well as an alternative states management system model. It must be noted that the state and alternative solutions management system needs to respond timely and appropriately, taking into consideration the integrity of business processes and available resources.

Contemporary information and communication technologies (ICT) have established themselves as a means of providing business systems support primarily due to their technological capability of processing vast amounts of information in a short period of time. Such processing is aided by scientific methods and techniques of business system modelling and design. Consequently, ICT and the solutions generated by them have become essential forms of business systems management support as well as the basis for the improvement of the efficiency of business systems themselves.

2. Features of complex business manufacturing systems

The success of a business system in a competitive market depends on, among other factors, the internal organization of the system. It is for that reason that business activities performed within the business system are integrated into units called business functions. Generally speaking, each business manufacturing system consists of three basic business functions: finance, marketing and production. Whereas the production function can be treated as an individual function, marketing and finance functions are considered as part of logistic support to production. The processes and activities that are conducted within the finance business function are related to the management of a business system's financial resources. From the perspective of a business system's input this is reflected in the procurement of equipment, raw materials and other materials; in the course of production financial resources are provided for the operational costs incurred; finally, when output is concerned, they are directed at investment returns that include the profit enabling further growth and development of the business system. The role of the financial function is to ensure a balanced and unhindered execution of processes and activities that occur within a business system regardless of the dynamics of the inflows and outflows of financial resources. The purpose of that function is fundamentally the same in unprofitable business systems too, although the manner in which resources are managed is somewhat different from that in profitable systems.

Marketing is the business function that ensures the development and improvement of products manufactured and services provided by a business system. Marketing and sales activities have an important role in finding customers and identifying their needs as well as in educating buyers and convincing them to use particular goods and services. The procurement part within the marketing business function ensures the purchasing of the required raw materials and other resources. Along with the finance function, its role is to provide conditions for initiating business processes and maintaining their constant development and growth.

The production function (production) is a set of business processes that create a particular material product or a service. Determinants of production are unique to each business system, with specific inputs, processing and outputs. Nevertheless, it is always connected with other business functions. This function is responsible for transforming inputs into certain outputs recognizable as a specific finished product. Moreover, this transformation is aimed at creating added value through finished products which can subsequently meet customers' needs. Without the added value, such a business system could be excluded from the supplier-manufacturer-buyer chain, as the buyers would be able to satisfy their needs directly from the supplier. Therefore, it is evident that creating added value is the essence of production. In business systems whose business processes are not based on processing materials (e.g. schools) creating an added value is measured by means of indicators which refer to socially useful values.

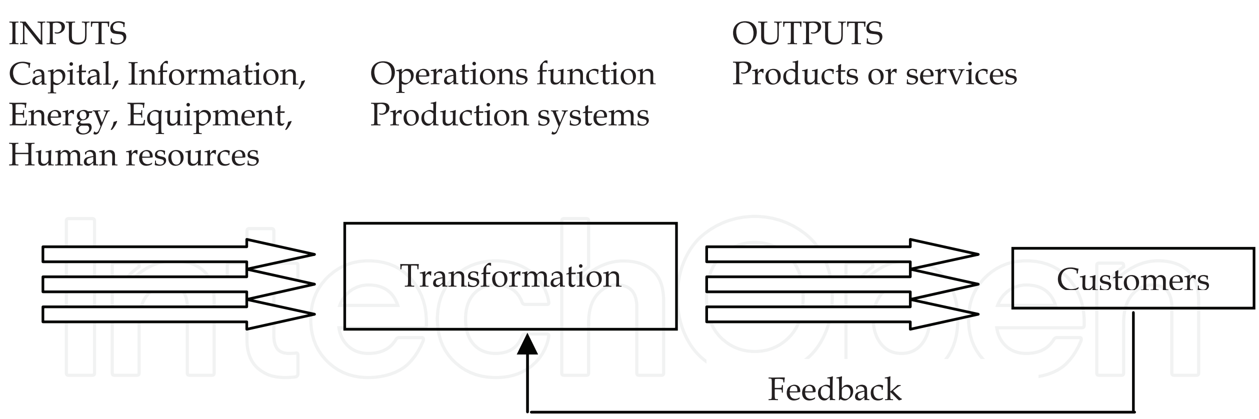

Fig. 1. Conceptual model of a business manufacturing system (Dilworth,1999)

2.1 Types of business manufacturing systems

Generally speaking, there is a large number of business manufacturing systems, each of them based on its specific product. However, there are certain features that they have in common. At the highest level of generalization, business systems can be divided into service and commodities manufacturing business systems (Dilworth,1999). However it is not easy to draw a clear line even at that level as contemporary business systems comprise both types of business activity (e.g. restaurants). The division into service and commodities manufacturing business systems is based on the fact that in case of service business systems the user is involved in the business system itself, whereas in commodities manufacturing systems business processes occur in separate processing locations that the user commonly does not participate in (Dilworth,1999). There are several general differences between service and commodities manufacturing business systems (Dilworth,1999):

- Productivity is easier to measure in commodities manufacturing business systems since in manufacturing 'tangible' goods are processed, while the evaluation of services is fairly difficult.
- Quality assurance is easier in commodities manufacturing business systems: in case of commodities it is possible to directly verify whether certain quality norms are observed in the manufacturing process, while service quality evaluation may be more subjective and depends on an individual user.
- In service business systems there is a direct contact between the personnel and the user, while in commodities manufacturing systems contacts between the personnel that manufacture the product and the user are not common. Relations with customers are more important in service business systems since the quality and type of service directly depend on that relationship. The marketing business function of commodities manufacturing business systems also includes customer relations, although it does not directly affect the execution of the manufacturing system.
- Commodities manufacturing business systems can use warehouses as support to their activity. On the other hand, for service business systems warehousing is not available so their productivity depends exclusively on the disposable time and work resources (service duration time, number of workplaces etc.). As a result, service systems use time sharing to minimize the number of rejected requests.

2.1.1 Service business systems

In service business systems the customer participates in business processes. There are several subtypes of service business systems which have certain characteristics in common. The first of them is the level of participation of customers in a business process. It refers to the character of the mutual relationship between the customer and the service system, that is, to the amount of time dedicated by the system to each particular customer. Consequently, this type of service can be viewed from the perspective of two levels of participation – individual and collective. The second feature is the level of complexity, according to which service systems are divided by the type of specific knowledge and skills, type of equipment or the quantity of material and financial resources needed for the execution of a job. As a result, services classified by this feature can manifest a higher or a lower level of complexity. Both features are mutually related so certain services can be classified according to both categories.

2.1.2 Commodities manufacturing business systems

Depending on the nature of the system, commodities manufacturing business systems can be divided into the following categories, according to the character of the manufacturing process:

- job shop
- repetitive manufacturing
- batch manufacturing.

Job shop is the term which refers to manufacturing of unique custom-made (or even hand-made) articles. Its distinctive features are a small quantity of manufactured items within a wide range of products aimed at increasing sales probability and a fairly high price. This calls for the procurement of general purpose equipment and employees with a broad knowledge base possessing a variety of skills. Manufacturing itself must be extremely flexible, unrestricted by a firm business structure and a continuous flow process. Since manufacturing planning, distribution and coordination are determined by the momentary situation, extraordinarily skilled management staff is generally implied in this manufacturing type.
Repetitive manufacturing is the term which refers to manufacturing of large quantities of identical or similar articles. This manufacturing type is distinguished by a firmly defined organizational structure with a predetermined business flow. Business processes are sets of linearly connected short-term activities, each of them different in relation to all the other activities involved. The outcome of such organization is workplaces equipped with special tools and machinery requiring highly-specialised staff. Material management and raw materials management presupposes an input and an output warehouse as the sole prerequisite for a continuous production flow. Provided all the conditions are fulfilled, the process of manufacturing a single item is very short indeed.
Batch manufacturing seems to be a compromise between the job shop and repetitive manufacturing. It is the prevailing manufacturing type in manufacturing systems. Batch manufacturing is distinguished by defining initial requests for manufacturing a particular product, with the process being finalized after it has been repeated a specified number of times. For each product manufacturing equipment is adjusted and process flows and manufacturing structure are redefined. Such an organizational structure of the system and equipment should be flexible enough to be easily adapted for new jobs. The key parameter in those changes is the time needed for the manufacturing process adjustment. The scope of the required changes, which implies a shorter time needed for adjustments, can be reduced by focusing the manufacturing to similar types of goods. This can result in lesser changes in organizational and material flow, the need to use specialised equipment and a possibility to automate production.

3. A glass container manufacturing business system

Manufacturing business systems, as a particular business systems class, share characteristics related to business processes. This implies that certain business processes can be unified and shown by means of a general business processes model for manufacturing business systems. By recognizing business processes and their individual characteristics it is possible to determine and describe system states, conditions and mechanisms of system states changes.
Manufacturing glass containers is an example of a commodities manufacturing business system. Due to its characteristics, it can be classified as a batch manufacturing system. This concrete manufacturing system is used in this paper as the basis for the development of a model of an analogous business systems class.
A glass container manufacturing system belongs to a group of systems combining continuous and discontinuous manufacturing (Bider, 2005). The product line of the manufacturing system observed is hollow container glass varying in size, shape, colour and purpose. Within a glass container manufacturing system two different types of manufacturing processes are combined. The first part, called the hot zone, is where glass

mass to be later used for glass container production is prepared and melted. This manufacturing phase represents the process-type (closed-type) continuous manufacturing of standard products. Other manufacturing operations, ranging from the molten glass separation to all the cold zone operations, are performed discontinuously using different types of machinery and equipment on each particular item within the product line. The product type is determined by the glass mix itself and the kind of glass-forming tool used, so this segment of production, owing to its features, represents the chain-type (open-type) continuous manufacturing of standard products. A basic outline of the functioning of the observed business manufacturing system is shown in Fig 2.

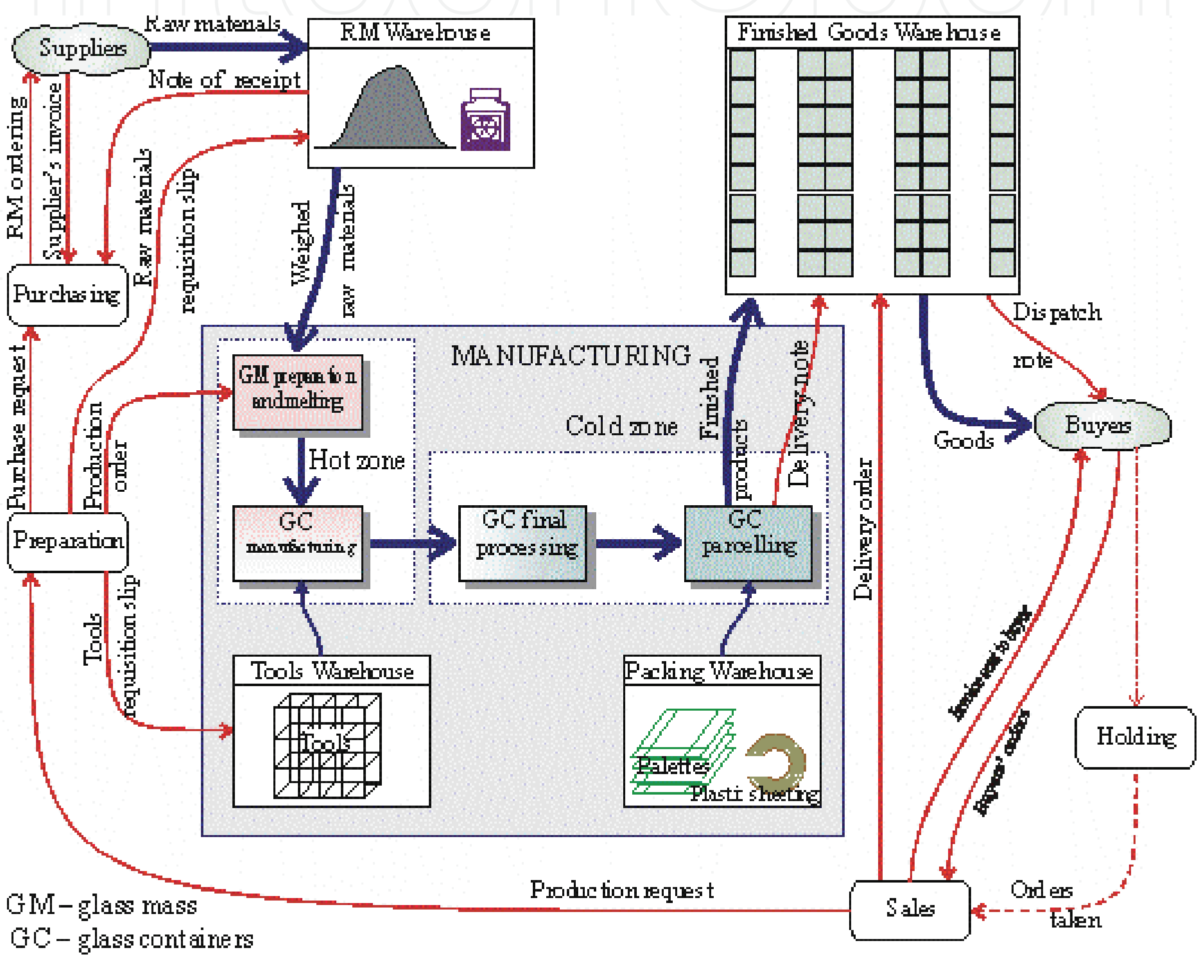

Fig. 2. Functioning of a glass container manuf. system's supply chain (Brumec et all, 1998)

In the raw materials warehouse materials and chemicals needed for uninhibited and continuous production of glass containers are stored. The renewal of supplies is conducted in accordance with the procurement plan and specific manufacturing requirements arising due to custom-made orders. A shortage of any raw material in the warehouse is not allowed as it may cause an interruption of production, which leads to closing down of the production line.

Tools and packaging warehouses are constituent parts of manufacturing since both tools and packaging are used in operations which are indispensable parts of the manufacturing process. The process of establishing the need for tools, as well as the ordering and receipt thereof is basically identical to that used in case of to raw materials. The need is defined by manufacturing preparation after which purchasing occurs. The ordered tools and packaging are stored separately, with the manufacturing preparation responsible for supplies inventory.

After the final manufacturing stage finished products are delivered to the finished goods warehouse. In repetitive manufacturing guided by buyers' orders, a finished goods warehouse represents a buffer between the contradictory requirements for continuity of the manufacturing process on one hand and virtually unpredictable buyers' needs on the other. Production management is therefore equally based on buyers' individual orders and warehouse inventory. Although the finished goods warehouse is the sole responsibility of the sales function, it is closely connected with manufacturing preparation in matters concerning the planning of the quantity and type of products as well as production deadlines. Managing a finished goods warehouse is a complex task since such goods normally require large storage space, tend to be fragile and become obsolescent soon. As a result, taking finished goods inventory needs to include both quantitative stock-taking of individual items and inventory of batches (by production date, prescriptions and tools used) taking into consideration their physical location within the warehouse.

Regarding the complexity of managing a manufacturing business system with a combined continuous and discrete manufacturing process, it is necessary to point out the following features of such systems:

- Although the entire product range is manufactured from glass mass of varying features, it can be said that, according to their composition and colour structure, there is a relatively small number of glass mass types.
- Glass mass documentation (containing information about its composition, process parameters and procedures order in the hot zone) has been developed as a set of prescriptions, whereas tools required for manufacturing different glass container shapes have been described by means of construction design and a document specifying their components.
- Production documentation incorporates the prescriptions and the production tools to be used for manufacturing the product.
- Melted glass mass is a semi-product that several different types of products arise from in a continuous flow. For technological reasons, the melted glass mass cannot be stored for later finalization.
- In case of demand for a new type of glass (which seldom occurs) new prescriptions are first developed and tested, upon which the appropriate tools for forming glass containers are developed and tested; in case of demand for a new type of glass containers (which frequently occurs) new tools are designed, constructed and tested. Tool modifications are 'easier' than those in a glass mass type as they require less time and turn out to be more profitable.
- Production resources are synchronized with the technological operations sequence so as to continuously produce various types of glass containers from the same glass mix, using different tools as long as the planned production quantity does not require a modification of the glass mix.
- The principal goal of the logistic chain is to timely ensure the quantity of raw materials needed for a particular type of glass mass, reduce the frequency and duration of production delays caused by a change of tools or glass mass type, and guarantee a high reliability of the technical production system.

The major reference value in production management is the product quantity and the time by which the product ought to have been finalized and made available.

4. Simulation modelling of manufacturing business systems

Using simulations in a business environment is determined by the goals of a business system. If we assume that the general goal of each business system is its survival in the market and business growth, as well as the development of the system, then simulations will be directed at improving the execution of business processes, attempting to forecast future situations and identify critical success factors for achieving the desired business goals (Visawan&Tannock, 2004). In literature on simulation various authors propose different definitions of the concept of simulation, which depends on the area covered in a particular book or paper or a specific field of interest of the author. While some of them interpret simulation as a representation of systems dynamics, a mathematically grounded numerical technique, experimentation or computer software operations, others define it as a process or a process modelling technique. In general, it can be said that simulation modelling is mimicking of a real system by means of scientific methods (probability theory, statistics and operations research) and contemporary information technologies. It is in this way that the simulation process and its capabilities are most precisely defined.

Simulation modelling methods are a powerful means of achieving qualitative changes. Working with models makes it possible to view business systems dynamics, which means that individual action scenarios can be generated and the system fine-tuned in short time segments (Manzini et all, 2005). Each system state described by a conceptual model contains formally determined parameters and conditions which describe it. By changing the values of state indicators defined in such a way a range of possible future states of the system is obtained along with precisely defined border values, and conditions and ways of transition from one state to another(Ingemansson& Bolmsjö, 2004). This eventually implies that it is also possible to implement less radical yet continuous changes in the course of a business process, predict future events, and plan the procedures accordingly. Based on them, the system of management and monitoring of possible alternative states is developed that can serve as a procedural pattern for manufacturing business system management. By unification and formalization of manufacturing business processes, and their upgrade with a view to develop a meta-model, it is possible to create a general model of business systems states management(Lau &Mak, 2004). If input in the form of concrete values of individual system parameters is provided, such a model can be applied to a concrete business system within the class for which a given meta-model has been generated.

4.1 Conceptual models

Simulation modelling of a manufacturing business system starts with the development of the system's model. Models are based on the analysis of a business system's elements, structure, relations and functions. Well-developed models provide useful information on problem-solving possibilities as well as on alternative solutions, possible negative effects and states in which a real system can be found if certain system parameters are modified. Contemporary modelling presupposes the application of computers in defining the requirements and model construction. Nevertheless, the entire modelling process is still based on the knowledge, logic, ability of abstraction and experience of the individual that develops the model so that the process cannot be fully automated. Using computers in the modelling process primarily refers to mathematical calculations of the value of particular parameters, since the complexity and the amount of such calculations grow exponentially depending on the increase in the number of elements that constitute a model. The first step in simulation modelling is the design of the system's conceptual model. Its purpose is to enable the structuring of the problem and its better comprehension. Conceptual models are important as they are meant to (Wenbinet all, 2006):

- isolate the essential characteristics of a system
- describe elements of the system and their interaction
- facilitate communication between the developers' team and model users
- assist in the computer model development.

Conceptual models contain a rough description of a system and its elaboration into separate modules. They represent a link between the problem-solving idea and the mental model of a real system on the one hand and strictly defined computer models that enable simulation of a system's behaviour on the other. There is a certain inaccuracy and inconsistency in representing a real system by means of conceptual modelling that originates from the inability to precisely determine the system's dynamic behaviour in time and possible occurrences of certain parallel activities in the system. Therefore a conceptual model is partly a general model, although one that can be viewed as a dynamic system in which objects of the model can also operate in parallel. Owing to these particular features, Petri nets are proposed as a suitable method for developing a conceptual business system model.

Petri nets, as a conceptual system modelling method, represent a means of modelling, researching and simulation of complex dynamic systems. They are used to predict the system behaviour and simulate future system states, besides determining the conditions of changes of system states. In that sense Petri nets are a special class of conceptual models which can be used for observing both current and future events, their sequence and conditions required for their occurrence and continuation (Wang et all, 2005).

In the observed glass container manufacturing system two separate segments can be recognized in the production function (Fig. 2) earlier referred to as the hot zone and the cold zone. In simulation modelling they can be represented as separate models that in a later stage of the simulation experiment will serve as the basis for determining the simulation type. Namely, as the production processes in the hot zone are performed continuously, the experiment will also be conducted by continuous simulation. On the other hand, the nature of the processes in the cold zone is discontinuous so discrete simulation proves a logical choice for simulating such a system. In modelling the hot zone the principal feature of that part of the production process needs to be considered, i.e. feedback system modelling. In doing so, methods and techniques of conceptual modelling in the domain of systems dynamics can be used that describe interactions between certain elements of the observed system. Figure 3 shows the model of hot zone functioning with feedbacks.

At the conceptual level it is possible to implement Petri nets for developing models of both zones provided that specificities of each of them are observed. In addition, Petri nets, as a fairly complex conceptual model, solve the inaccuracy inherent in causal loops. Petri nets show possible resources conflicts and the way in which they are resolved. Also, they highlight solutions for deadlocks, states conversion resulting from conflict resolution, and similar adverse system states. Petri nets (especially coloured Petri nets) fairly precisely describe system states conditions (continuous process with feedback), including a process network net, that is, the way of performing processes and states conversion.

The following entities are included in the hot zone: raw materials, mixer, mixture, furnace, monitoring and control system, and glass mass. Each of these entities is modelled by a Petri net, all of which are subsequently integrated into a model representing the entire system. Figure 4 shows the conceptual model of the control system which manages production processes in the hot zone in an automated manner. It ensures the continuous execution of the process by initiating certain actions based on the fulfillment of conditions.

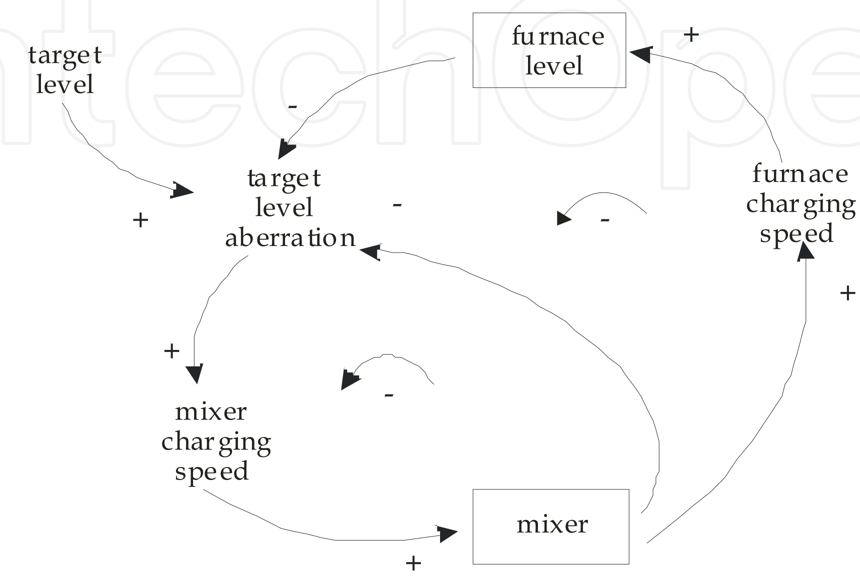

Fig. 3. Conceptual model of a causal loop

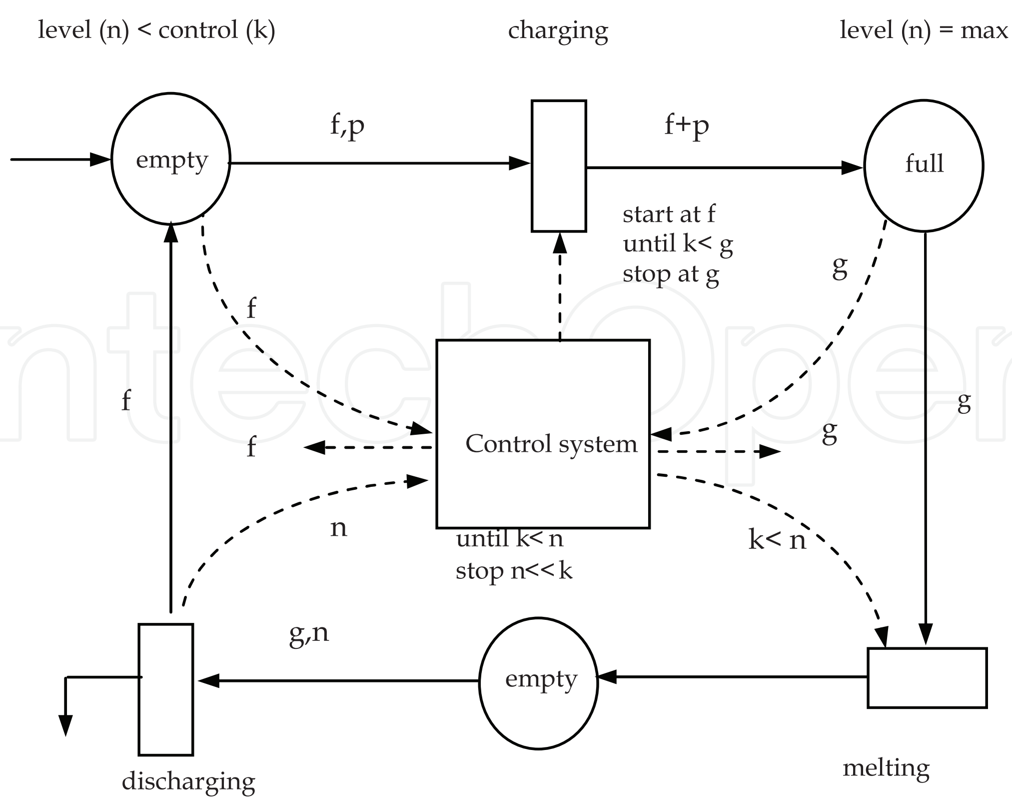

Fig. 4. Coloured Petri net of the hot zone control system

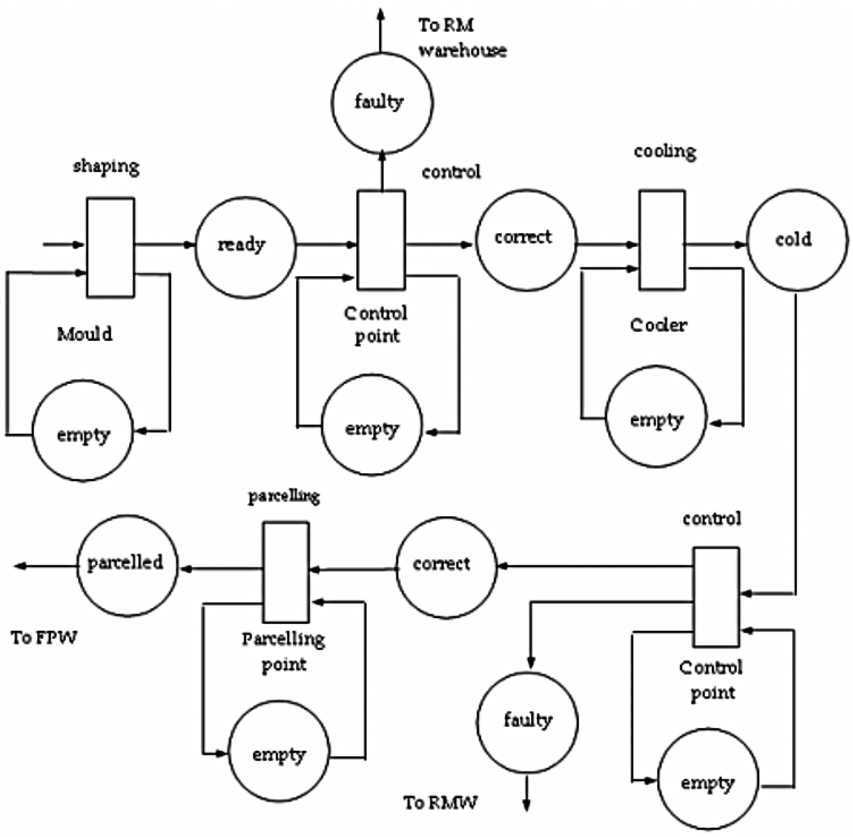

Fig. 5. Cold zone Petri net

The cold zone is the segment of the glass manufacturing process that comprises the final processing of glass containers until the moment when they are dispatched to the finished goods warehouse. In this segment of production glass containers undergo several subsequent processing stages before they are dispatched to the warehouse during which their characteristics remain unchanged.

This part of the manufacturing process is characterized by processes occurring on the assembly line. In other words, the assembly line conveys objects of processing from one processing site to another at which a specific action is performed. Apart from glass containers as the transitory entity the conceptual model of the hot zone also consists of entities that represent service points (production resources).

The process of conceptual model development ends with model validation that represents the verification of the correct logical functioning of conceptual models with regard to the real system. Validation is usually repeated during model adjustments until the desired acceptance level of the model is achieved. It is important to emphasize that by validation it cannot be determined whether a certain conceptual model fully corresponds to the real system. Instead, validation can establish that a certain level of equivalence with the real system is achieved.

4.2 Simulation models

Knowledge of a system's characteristics upon which a model is developed is not sufficient for successful simulation execution. Each real system, apart from its constituent elements and relations between them, has its function, or the way in which the elements and relations between them interact. Owing to this systems dynamics is achieved, which leads to creation and exchange of certain system states. This means that in the process of simulation modelling a system of a model's behaviour is required along with the system's model itself, including the rules and algorithms of interactions among elements of the real system represented by the model(Kunnathuret all, 2004). Development of a computer simulation model of the hot zone is based on a set of business system features that are defined and described by the conceptual model. Conditions and assumptions from the conceptual model for the observed class of manufacturing business systems that execute part of their business processes in a continuous manner determine the implementation of systems dynamics as an appropriate method for the description of continuous business processes that include feedback. Feedback relationships among hot zone attributes are shown in the regulatory cycle in Figure 6. It shows systems dynamics attributes of entities in the hot zone as well as the direction in which they operate.

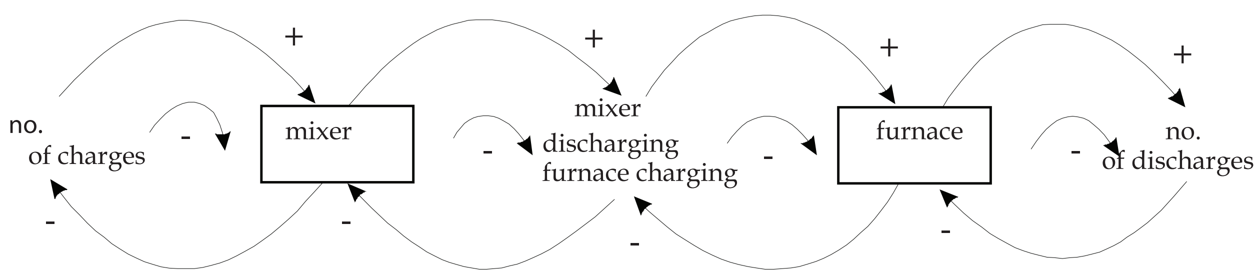

Fig. 6. Causal loop diagram of the process of glass mass preparation and melting

Systems dynamics that describes feedback systems is characterized by three key features:

- *level* – refers to the state of a resource or its accumulation;
- *rate* – refers to the rate of transforming resources from one state to another, that is, to level change rate;
- *delay* – refers to the time needed by the system to respond to the initiated action.

If the delay is shorter, the system can operate in a balanced way without drastic changes in behaviour and functioning. On the other hand, in case of a longer delay, oscillations arise in the functioning of the system (Doloi&Jaafari, 2002).

Features of hot zone systems dynamics and manufacturing processes therefore determine the manner in which a simulation model will be developed by a set of difference or differential equations that describe the states and conditions of changes of hot zone states. After the description of the system by means of a simulation model, programming is used to develop an application that will perform the simulation experiment on a computer.

By performing the simulation experiment data is obtained that demonstrate the way of a particular business system's functioning. The experiment is first conducted with data gathered in the real system to verify the computer model and the simulation program. Verification is the process of comparing the conceptual model with the computer model with a view to determine the equivalence in the functioning logic and certain parameters between the two models. The aim of this step is to establish whether all the important features of the system in the conceptual model are sufficiently well translated into the code of the computer simulation programme. Only after the validation and verification have been successfully performed is it possible to determine whether the results of simulation experiment will be sufficiently accurate and reliable to serve as the basis for making appropriate business decisions. However, apart from allowing for model verification, the comparison of results and analysis of simulation results confirmed that the system which controls furnace recharging does not operate under optimal conditions.

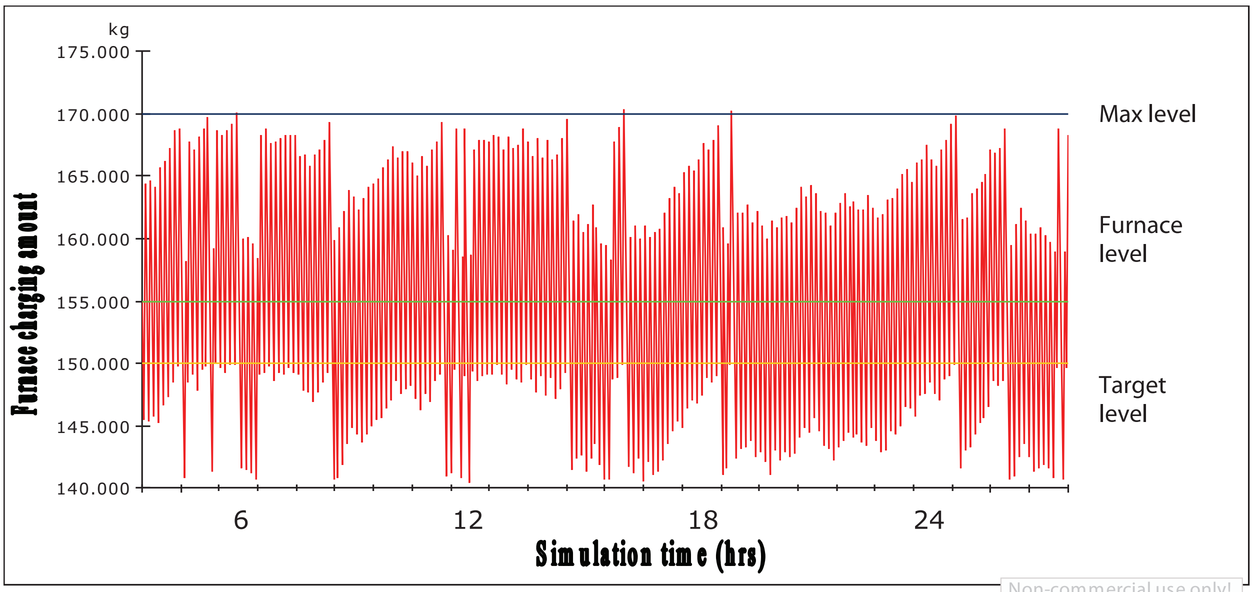

Fig. 7. Simulated furnace level state

Simulation experiments of the hot zone showed that the control system for the management of furnace operation cannot simply maintain the target level of the melted glass mass in the furnace at the currently defined parameters. In Figure 7 significant oscillations in the mean values of the level state and their aberration from the desired value are evident. In a real system this means that the manner of functioning of the control system is a stochastic function. In other words, the control system performs its activity, but the patterns of its functioning are not easily predictable.

Constant aberrations from the target level lead to the initiation of the furnace recharge cycle. Their total number is within the predefined values, but the duration of the cycle is long. As furnace discharging is executed continuously, and the glass mass level oscillates around the target level, a large number of level states assume values close to the minimum or even below it, which is potentially harmful as it can lead to system interruptions. Under normal circumstances they will not occur, but it still represents a permanent load that initiates regulation mechanisms. The control system for the management of furnace operation thus continuously generates control signals for process monitoring that should result in the desired state, but the system responds slowly and rarely achieves the desired state. Furthermore, the control system functions in a stochastic environment, without predictable functioning patterns, which increases the complexity of its functioning (i.e. the number of possible systems states and, consequently, patterns of functioning, is increased, which leads to a more complex decision-making process).

Such a scenario is certainly not desirable if a general states management model is to be defined for a particular type of business processes. The general meta-model of management should be simple, with a (relatively) small number of possible states, an easily predictable pattern of behaviour and clear conditions for state transitions. Therefore it is necessary to first implement certain changes in the model that will result in its better (that is, safer and

simpler) functioning. It is only then that the meta-model of states management should be defined.
The cause for such functioning of a management control system is the fact that the system's response to control signals is very slow. Research into technological processes has shown that the delay amounts to 15 minutes. The analysis of a conceptual model developed by a Petri net showed that this delay can be reduced. Figure 8 shows the proposed redesign aimed at shortening the delay.
In the real system model, after the signal indicating that the minimum furnace level has been reached is generated, the process of furnace recharging is initiated. The process starts at the raw materials warehouse. For all the actions in the technological procedure to be carried out, 15 minutes are needed. If the control signal of the level state is directed to the mixer by feedback at the moment when the mixer is already charged, the system's delay is reduced and amounts to only 7 minutes.
The duration of the delay cannot be further reduced as this time is used in the business system for technological actions between the mixer and the furnace and includes certain transportation activity as well as preparatory actions for furnace recharging (preparation and charging of furnace pre-chambers, temporary interruption in the melting process etc.). It should be taken into consideration that the entire manufacturing process is continuous, and the level to which the mixer is charged is the consequence of a previous state that can defined as the initial state at a given moment.

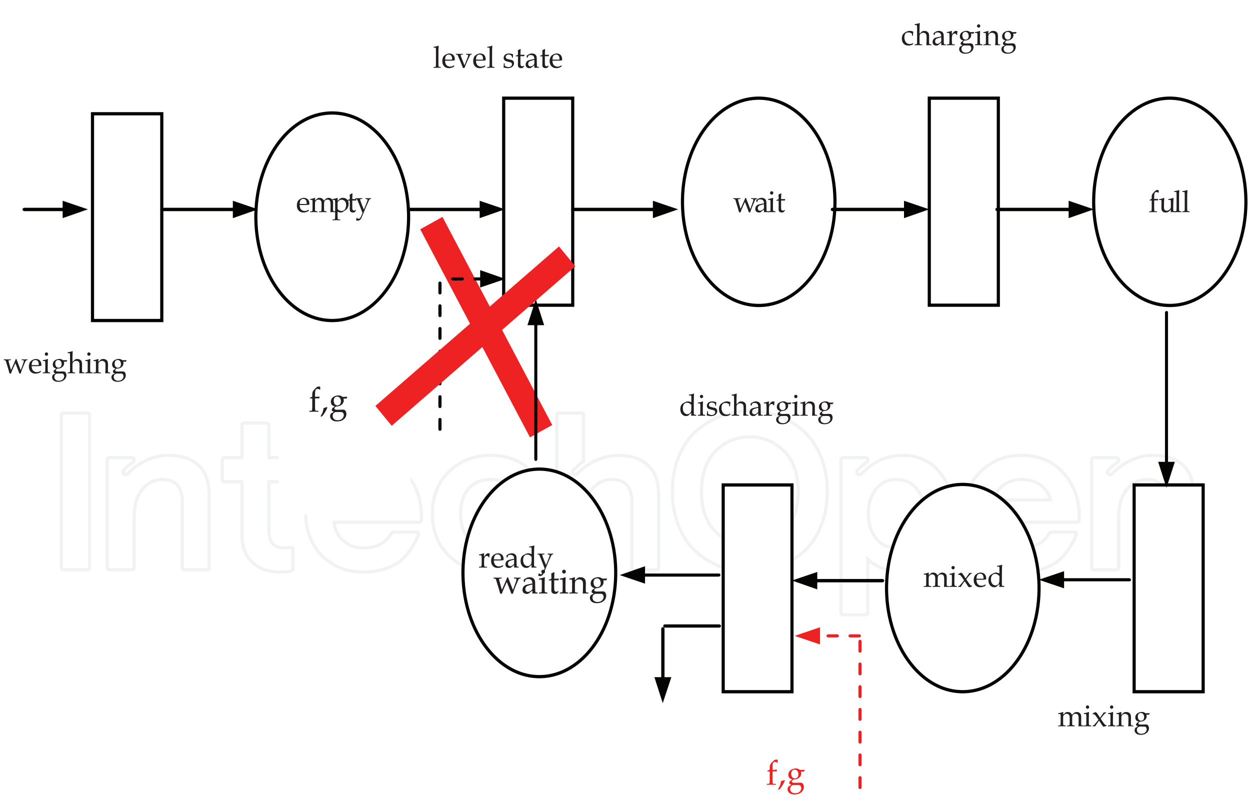

Fig. 8. Redesigned management

The currently observed state includes peak furnace load, with three production lines and different products, which requires a change in defining the state of the mixer level. Namely, the mixer level was previously defined as:

init 0 kg

Mixer level = +()dt – (Furnace charging rate)dt

d(Mixer level)/dt = Mixer charging rate (t) – Furnace charging rate (t)

The dynamics of mixer charging and discharging remains unchanged, but the definition of the initial state changes as well as the definition of the level itself. As a result, in the changed system the mixer level state is defined as:

init 500 kg

Mixer level = +(Mixer charging rate)dt – (Furnace charging rate)dt

d(Mixer level)/dt = Mixer charging rate (t) – Furnace charging rate (t)

In this way the condition which states that the mixer should always contain a sufficient amount of prepared mass regardless of the type of product manufactured on a particular line is fulfilled. In this model this value is constant for each instance of charging. As it is common that in the system the mixer is discharged entirely every time, this manner of changing the mixer level is maintained in the modified model as well.The proposed change does not require technological changes in the manufacturing process, and only refers to changes in the reverse cycle of information.However, the implemented changes entail major changes in the control function of the system for the management of furnace operation. Figure 9 shows simulation results for the redesigned model. It reveals that the changes introduced in the reverse cycle, which result in a reduction of delay, positively affect the functioning of the control system for the management of furnace operation. Balanced functioning of the control system is thus achieved as changes in furnace level states have a continuous flow in a particular direction.

Changes result in visibility of particular states of the observed system (i.e. processes related to discharging and recharging states can be monitored) and make it possible to more clearly define the conditions of transition of one state into another. This clear and continuous sequence of states is established as a default, which increases the predictability of the next state and simplifies states management. In other words, the control management system generates the identical type of control signals, in the identical sequence until control signals for the change of the sequence occur, which in turn results in the identical direction of the state sequence until the control state is reached. Such simple functioning can be generalized and described as a self-regulating management system for identical types of manufacturing processes. Moreover, it should not be disregarded that that such a manner of management can also be derived by means of mechanical dynamic automatic devices so that it is not necessary to use information systems and ICT solutions for system states management and control.

The simulation model of a production line comprises a set of manufacturing operations for the production of each particular glass container, from the very beginning of the line to product paletting as the terminal activity, and all the operations in between.

In the observed real business system this segment of production is performed continuously, with certain events occurring under the influence of the transactions that pass through them. Therefore it is possible to describe this part of the manufacturing system by a discontinuous simulation model. The production line of the observed business system is an assembly line that conveys glass containers from one processing location to another. At each point the processing capacity and time determine how long a certain glass container will be held at that location. The process is automated and monitoring and troubleshooting of possible delays on the assembly line is done by employees that supervise each particular processing location.

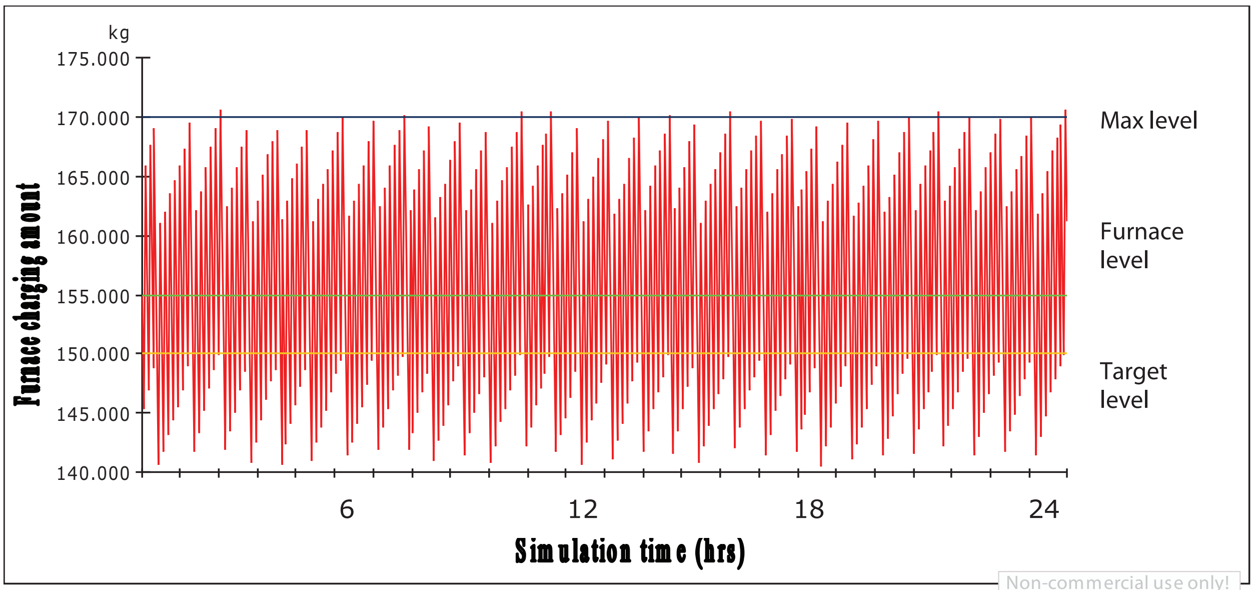

Fig. 9. Furnace level state after management redesign

The idea to be confirmed by means of simulation modelling is to investigate the possibility of manufacturing various glass container types by using a disposable number of production lines (that is, three production lines connected to the furnace). The production employing three production lines amounts to peak cold zone load. Possible combinations of simultaneous manufacturing of products in production lines whereby technological conditions of the manufacturing process are fulfilled need to be explored.

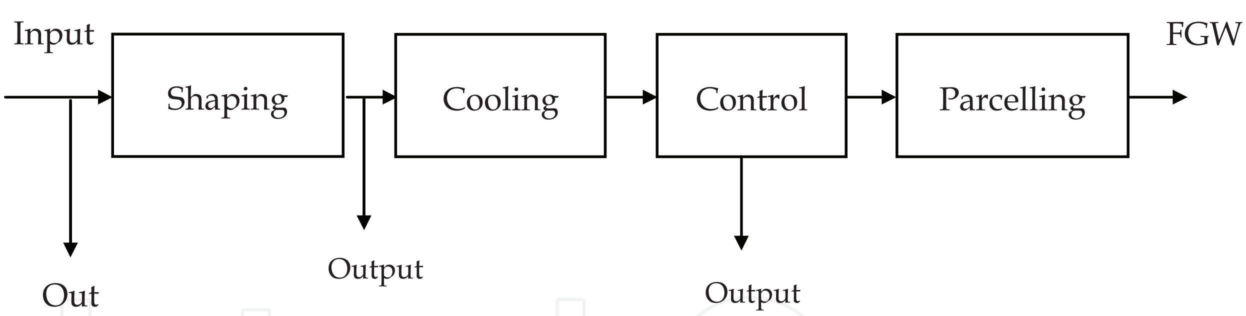

Fig. 10. Production line of glass container manufacturing

The principal condition to be observed in the model comprising three production lines is the maximum utilization of the melted glass mass, paralleled with the maximum utilization of production capacities. This means that production resources of production lines need to operate at the peak utilization degree, the prerequisite for which is a sufficient quantity of the melted glass mass.

Results of simulation experiments (Table 1) showed that simultaneous manufacturing of various types of products in disposable lines for container manufacturing is possible. In this way it was also confirmed that improving production planning, in other words, the dynamics of managing the production by means of orders, is possible. Using a particular combination of product manufacturing can be partial or total, depending on the production needs, delivery deadlines, finished products inventory, and other external factors (e.g. availability of glass mass within the same group to which the observed business system belongs).

Model	No. of inputs by mould capacity	Amount by no. of inputs (kg)	No. of inputs used in the model	Amount by no. of inputs used (kg)	Amount disposable by the beta distribution (kg)	Difference real/sim (kg)
"AAB"	92160 + 40320	37232,64 + 19353,6	91979 + 40046	37159,51 + 19222,08	58.222,44	+1636,2 +1840,85
"AAC"	92160 + 43920	37323,46 + 19324,8	91979 + 44133	37159,51 + 19418,52		+1574,18 +1644,41
"ABB"	46080 + 80640	18616,32 + 38707,2	45990 + 80093	18579,96 + 38444,64		+898,92 +1197,84
"ACC"	46080 + 87840	18616,32 + 38649,6	45990 + 88265	18579,96 + 38836,6		+956,52 +805,88
"ABC"	46080 + 40320 + 43920	18616,32 + 19353,6 + 19324,8	45990 + 40046 + 44132	18579,96 + 19222,08 + 19418,08		+927,72 +1002,32
"BBB"	120960	58060.8	120139	57666.72		+161,64 +555,72
"BBC"	80640 + 43920	38707,2 + 19324,8	80093 + 44133	38444,64 + 19418,52		+190,44 +359,28
"BCC"	40320 + 87840	19353,6 + 38649,6	40046 + 88265	19222,08 + 38836,6		+219,24 +163,76
"CCC"	131760	57974.4	132398	58255.12		+248,04 - 32,68

Table 1. Overview of planned, disposable and simulated glass mass amount and product units

5. Conclusion

Researching manufacturing business systems does not only enable to collect measurable data on possible system states and parameters applicable inside and outside a business environment, but also to determine conditions and causes that lead to changes of business system states. Defining initial models by using Petri nets enhances the simulation modelling process since the defined models that are formally described at the conceptual level make the process of conducting experiments on simulation models more efficient. The validation of the defined models improves their trustworthiness, which in turn contributes to the certainty of the final results obtained by the simulation experiment. Verifying possible alternatives through simulation experiments and validating the results of those experiments improve the reliability and quality of future business system design. In this way the quality and reliability of decision making in the process of system design is also enhanced, as it is based on verified alternative models. An optimal business systems design mode is thus obtained, which eventually results in rational utilization of business resources.

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Todayâ€™s global economy offers more opportunities, but is also more complex and competitive than ever before. This fact leads to a wide range of research activity in different fields of interest, especially in the so-called high-tech sectors. This book is a result of widespread research and development activity from many researchers worldwide, covering the aspects of development activities in general, as well as various aspects of the practical application of knowledge.

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