Business Process Reengineering of Complex Production Processes Using Simulation Modelling

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Abstract. *To obtain a competitive advantage in the market, enterprises are forced to introduce permanent changes in own business systems. There are various methods for applying such changes, one of which is Business Process Reengineering (BPR). The success and quality of BPR is in direct correlation with the success of the entire enterprise. The fact that the introduction of BPR closely depends on the context of each particular case explains why a universally applicable procedure for conducting BPR has not been devised yet. Simulation modelling is a possible method of BPR that can help to increase the quality and efficiency of BPR through experimental model design. Possible simulation modelling application in BPR is aimed at collecting data for performing modelling and developing a current business system model. After the experiments are done, a new model can be developed. Upon verification and experimentation of the new model, possible improvements in business processes are identified. By developing a simulation model yielding quick results it thus becomes possible to anticipate system states. The paper presents an example of using simulation modelling in BPR of a glass production system.*

Keywords. BPR, simulation modelling, glass production, methods, system models

1. Introduction

Business system reengineering is a systematic approach to improving business processes. Within this concept business processes of a business system are comprised and integrated in a way that individual or team responsibility pertaining to a particular business function is shifted to the business process as a whole. Reengineering results in redesigning of individual business processes or their isolation from a business system on one hand or the introduction of new business processes into the business system with a view to creating new value in the business system and gaining the competitive advantage in the market. Michael Hammer [5] defines business system reengineering as '... the fundamental rethinking and radical redesign of business processes, organizational structure, management system, values and beliefs to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed.' Successful business performance is reflected in a business system's ability to survive and thrive in a competitive environment. This ability relies on the system's capacity to perform tasks in compliance with standards and on time. Considering that contemporary business processes are performed by specialised expert teams rather than individuals, the coordination of parallel and phases activities conducted by individual teams has become a key factor determining how timely and effectively a business system will respond to changes in its environment.

Changes in the environment occurring at a high rate require a considerable elasticity of a business system during reengineering. Therefore business system reengineering can either be pursued as a means of enhancing a particular business system, which is an approach yielding immediate results, or as business system reengineering itself, which implies changes requiring a strategic shift in a company's business. Reasons for this distinction lie in key success factors of a business system and their current relevance and priorities regarding changes in the environment. Two different types of business system reengineering can thus be distinguished, namely, strategic and tactical business system reengineering [5].

Strategic reengineering, based on the top-down approach, comprises changes in business processes at the management as well as – partly – operational level of a particular business system. It is notable that for these changes to be conducted a thorough long-term analysis of a business system structure and the relationships within it is necessary. Tactical reengineering, on the other hand, concerns the tactical level and is conducted at the operational level of a business system and its processes in accordance with the bottom-up approach. As a result, such a business system will be able to respond quickly to changes in the environment, provided the changes are closely focused. Regardless of the type of reengineering, it should be aimed at ensuring that [4]:

- the organisation is founded on entire business processes rather than fragmented tasks
- the processes are managed by those who benefit from results of these processes
- information gathering and processing is performed by those generating it
- geographically dispersed system resources are observed in a more centralized way
- parallel activities and coordination thereof are linked
- quality control becomes an integral part of a system, and not an external process
- data is entered in the info-system only once, from the very location it is generated at.

Although the implementation of reengineering depends on the initial vision of the projected final outcome, the features of the business system and its environment tend to be the most common factors restricting the scope of reengineering. If business system reengineering is to be conducted properly, specific information necessary for making decisions on initializing the very process of reengineering as well as choosing a methodology for its implementation and problem-solving in given circumstances need to be provided first. By using the developed system analysis methods, information needed for proceeding with the reengineering can be obtained even in conditions in which the occurrence of certain events is not certain.

Simulation modelling refers to simulating a real system by means of scientific methods (probability theory, statistics, operations research) and contemporary information technology. It relies on a unique set of concepts allowing for unambiguous communication among all the participants in the modelling process. Apart from ensuring unambiguous communication, such a set of concepts determines the framework within which individual constituent elements of a model or a real system, as well as particular stages of the modelling process, can be distinguished. Since the goal of simulation modelling is to thoroughly analyse the behaviour of an existing system or its proposed counterpart, its objects include any complex physical or abstract systems functioning in accordance with certain logical principles or laws. Within simulation modelling a vast number of procedures used for real system modelling are comprised, and the choice of a particular procedure to be employed depends on the type of system to be modelled and its specific features as well as the problem to be solved.

Simulation modelling is a convenient tool for systems analysis and preparation of true and accurate information needed for reengineering initialization as well as determining the domain that the ‘optimal’ (In the context of simulation modelling, there is no optimal solution such as that in mathematical programming; 'optimal solution' in simulation modelling refers to any sufficiently good solution obtained within a predefined limit) solution lies within [7]. Simulation modelling has at its disposal various techniques and procedures powerful enough to be used for developing and validating solutions occurring as potentially optimal solutions in the reengineering process. Thus simulation modelling becomes a powerful tool for selecting the optimal solution as well as for validating the selected solution effects. Owing to singular features of continuous and discrete manufacturing processes with partial self-regulation, systems dynamics is the tool by means of which noteworthy results in that respect can be obtained.

2. Features of manufacturing business systems

The reengineering of manufacturing business systems is based on the reengineering of the manufacturing process. It is the features of that process that provide the source of data to be processed and that which all the other business processes and functions are based upon. This primarily refers to processes which belong to a business system’s supply chain which, along with the manufacturing process, constitute processes in which value is created, that is, processes pertaining to a business system’s value chain. All the other processes involved in task-performing merely ‘process’ the data arising in the value chain. By using data obtained in that way as well as that in the business system’s environment, decisions are made at all levels of business system management[13],[6].

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

a) job shop
b) repetitive manufacturing
c) batch manufacturing.

Job shop is the term which refers to the 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 rather 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 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 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 being different in relation to all the other activities involved. The outcome of such organisation is workplaces equipped with special tools and machinery requiring highly-specialised staff. Material management as well as 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 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 organisational 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 organisational and material flow, the need to use specialised equipment and a possibility to automate production.

3. Distinctive features of a glass container manufacturing system

A glass container manufacturing system belongs to a group of systems combining continuous and discontinuous manufacturing [1]. The product line of the manufacturing system to be observed is hollow container glass of varying 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 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 chain-type (open-type) continuous manufacturing of standard products. A basic outline of the functioning of the observed business manufacturing system is shown in Figure 1.

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.

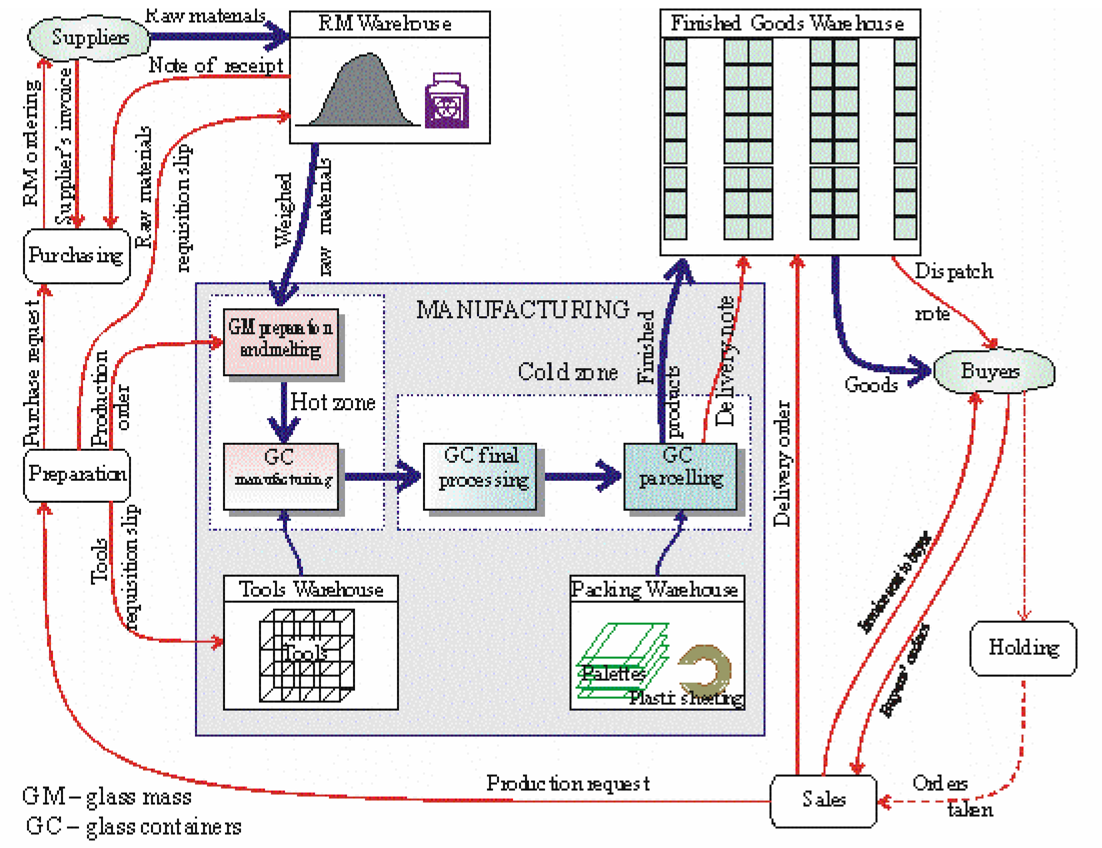

Figure 1. Functioning of a glass container manufacturing system's supply chain [3]

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 applying to raw materials. The need is defined by manufacturing preparation to be carried out by purchasing. The ordered tools and packaging are stored separately, with the manufacturing preparation being responsible for the inventory of their supplies.

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 planning 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 a lot of storage space, tend to be fragile and become obsolescent soon. As a result, taking finished goods inventory ought 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) the 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, as well as guarantee a high reliability of the technical production system. The major reference value in the management of production remains the product quantity and the time by which the product ought to have been finalized and made available [3].

4. Glass container manufacturing simulation model

The glass container manufacturing process is a sequence of processes and activities performed both in a continuous and discrete way. Therefore the entire system needs to be represented by means of two separate models. In each of them a different way in which production processes occur is shown. Moreover, such a division is notable within the business system itself, so that processes and activities pertaining to each of the two production types are easily discernible.

4.1. The conceptual model of the hot zone

The term conceptual model refers to a rough description of a system further elaborated into individual modules. This model type is the first formal description of a system used in simulation modelling for identifying connections and relationships between entities within the system, which is essential for a further formal description of system functioning by means of a computing simulation model.

The hot zone consists of the preparation and melting of the glass mass and forming of glass containers. The glass mass preparation and melting stage consists of two mutually connected business activities. The performance of each of those activities affects the execution of the other. For each of the two activities it is necessary to develop their own conceptual model. The conceptual model itself is developed by means of an activity cycle diagram. Owing to the nature of the continuous manufacturing process which virtually never comes to a halt, it is hard to determine the beginning of such a process. However, it is possible to consider the input of raw materials as the beginning of the manufacturing process. In Figure 2. the entire hot zone activity cycle diagram is shown.

4.2. The conceptual model of the cold zone

The term cold zone refers to the part of the glass manufacturing process which encompasses the final processing of glass containers until they are delivered to the finished goods warehouse (Figure 3).

In this part of the manufacturing process glass containers undergo several sequential processing stages before their final delivery to the warehouse, without changing its features in the process (the GLASS CONTAINERS entity is not transformed into a new form until the end of the process, and thus does not generate a new entity). The glass containers formed in the hot zone at the end of the process becomes the object of processing in the cold zone. Here manufacturing processes and activities occur sequentially, but discontinuously, with each particular glass container initiating a certain event, that is, a system state change.

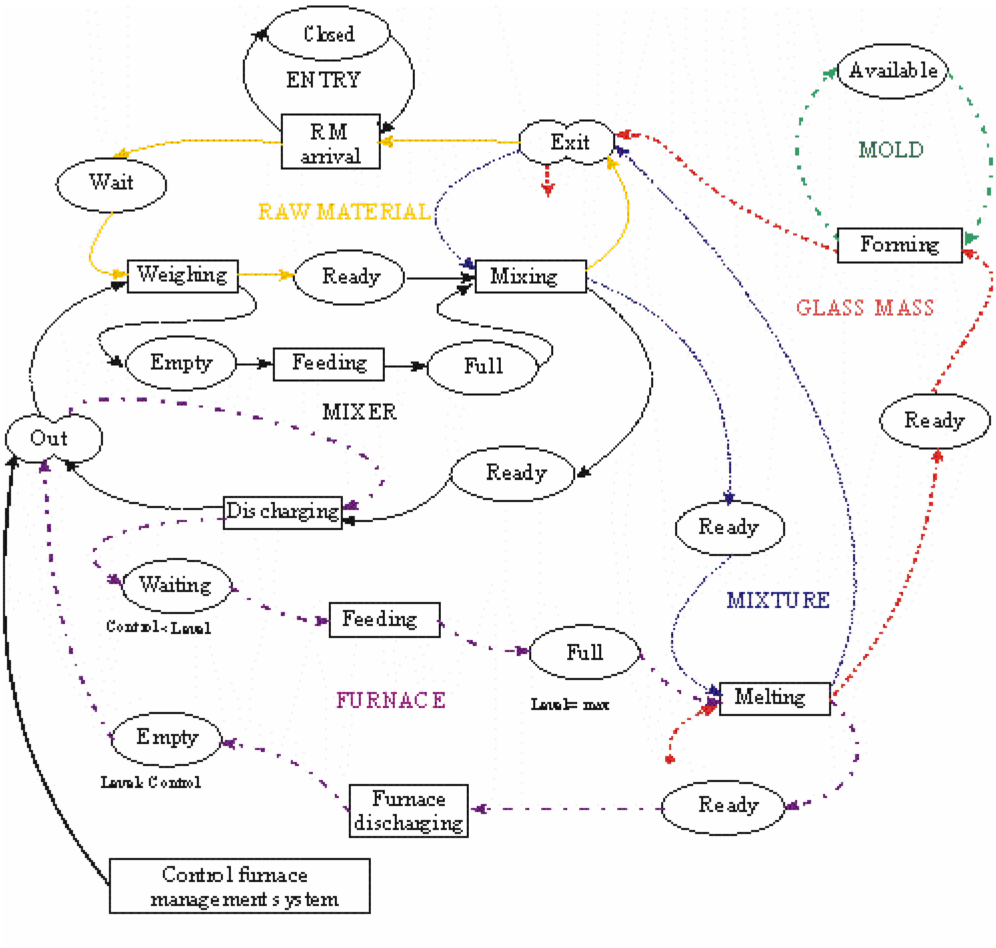

Figure 2: Hot zone activity cycle diagram

4.3. The computing model of the hot zone

Manufacturing processes in the hot zone are continuous and can therefore be shown by means of systems dynamics or, more precisely, a negative feedback model (process management is done in accordance with the predefined parameter limit values, with actions initiated by variable values exceeding the predefined limits with a view to stabilising the system). In a business system negative feedback management and action initiation are completely automated. The human factor, on the other hand, supervises the operation of the automated management system and monitors its operations over a period of time. The management and monitoring system is a part of the FURNACE entity and has been called a control furnace management system. The function of this system is to monitor the parameters of technological production of glass in the melting furnace and accordingly emit control management signals for processes occurring during glass mass preparation and furnace feeding.

Figure 4. shows the systems dynamics of glass mass preparation and melting processes monitored by the control management mechanism.
Generally speaking, this model shows a self-regulating negative feedback, so that the control function of the furnace management system cannot be discerned from this diagram showing glass mass preparation and melting processes.

The control function of the furnace management system is based on the tolerance of the level of glass mass melted in the furnace as the control parameter (Figure 5).

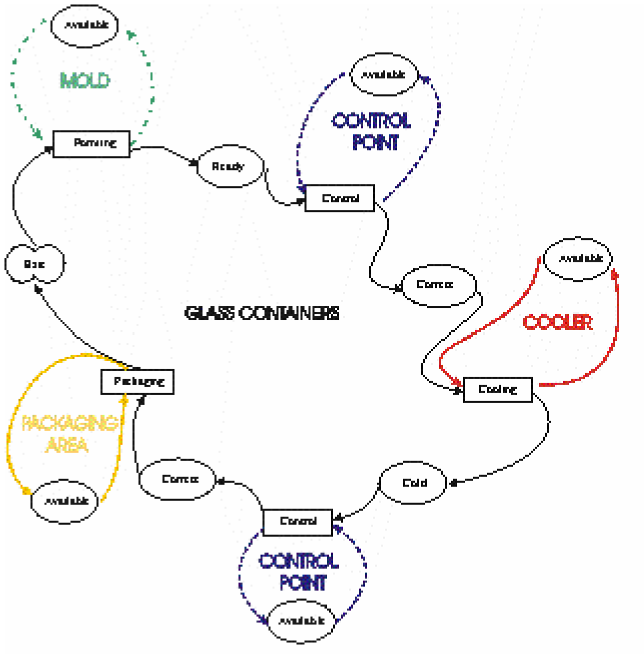

Figure 3: Cold zone activity cycle diagram

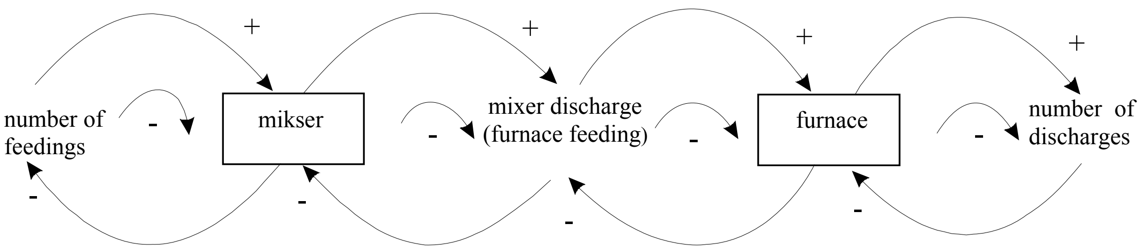

Figure 4. Causal loop diagram of glass mass preparation and melting processes

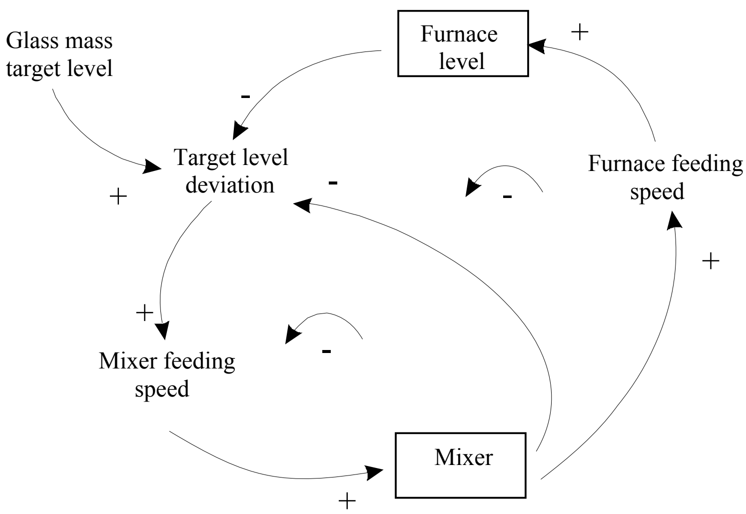

Figure 5. Furnace management control system

4.4. The computing model of the cold zone

The cold zone includes a sequence of manufacturing operations encompassing the manufacturing of each particular glass container. Within a business system, this part of production occurs continuously, with certain events being influenced by transactions of individual glass containers. Therefore this part of the manufacturing process can be described by a discontinuous simulation model. The transition from a continuous to a discontinuous part of manufacturing occurs in the MOLD entity. In other words, it is at this very part of the manufacturing process that the transition from a continuous simulation model to its discontinuous counterpart takes place. The hot zone model is thus strictly defined and guided and no major deviations in it are allowed or, for that matter, possible. This fact enables for a more complex, continuous model to be substituted by a simpler, discontinuous one. For that an unambiguous variable that will properly represent both models needs to be defined. Owing to the specific features of the glass container manufacturing system, this variable has been defined as the total quantity of the available melted glass mass. This variable can be expressed by the same units of measurement in both models and acts as a linking variable between the two models as it represents the exit from the continuous and the entry into the discontinuous model. Figure 6. shows a cold zone model.

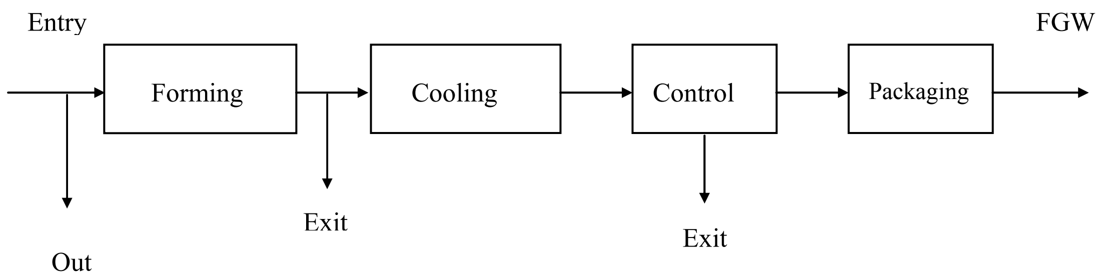

Figure 6. Glass container production line

5. Conclusion

Business systems are a constituent part of the environment they operate in. However, to survive and thrive in that environment, they need to comply with the conditions imposed by their environment. A business system can either gain or lose its qualitative advantage can owing to its internal organisation and the way in which business processes within the system are executed. Effective exploitation of available resources within a business system is reflected in its competitiveness being a measure of external success. Owing to the dynamic nature of business systems, it is evident that a single structure and relationships within a system, once established, will be not able to permanently contribute to increasing competitiveness of the system – or maintaining its current competitive status – if they remain unchanged. This explains why the initiative for business system reengineering, to be conducted professionally, accurately and timely by using appropriate methods and techniques, is justified indeed.

Nevertheless, full-scale business system reengineering is not always possible to pursue due to restrictions within the business system itself (manufacturing technology of particular products), so the scale of reengineering is often limited to improvements in the existing business processes. Business process improvement can be introduced by means of methods and techniques that do not only ensure a high quality systems analysis but also recognize the potential of the suggested solutions and prove their true potential and merits in practice. By all means, simulation modelling is one of those methods.

Unlike classical systems analysis and reengineering methods, simulation modelling features the ability to show the dynamics of business processes over time. This results in more accurate descriptions of possible multiple system states essential for individual business systems to take place. Simulation experiments, if performed repeatedly, can contribute to a system’s fine-tuning, which in turn facilitates the process of system management, as it allows for preparation of various scenarios intended for various changes of input traits. By evaluating particular scenarios according to the predefined business goals, modifications and improvements in business processes can be introduced.

6. References

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