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Overview on optimization criteria for production activities

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1 Introduction

Optimization is defined as minimization or maximization of cost function with variable input parameters. The word optimization commonly refers to the mathematical handling of parameters in order to maximize or minimize a mathematical function. It is, however, possible to use the word to describe handling of more complex systems. This makes optimization of various systems an increasingly important activity. Optimization can, at least to some extent, be applied on all system levels. However, the expected results are likely to be less consistently "good" the larger the systems are, for various reasons. The main problem with large system optimization is that there can exist major disagreements on what an optimal system is and how to measure if it is optimal.[6]

In order to optimize the production process, company has to have the ability to identify their main bottlenecks in production process. They need to be able to set the proper goals, i.e. grouping company's activities into modules and set the control points. Before setting up a optimization strategy, manager should answer the questions listed below:

- Identify bottlenecks and determine the level of resources necessary to achieve production targets.
- Provide accurate, objective, quantitative information to improve the process and increase productivity.
- What is the company strategy and how should the goals be clearly defined?
- Identify measurement, calibration methods and frequency.
- Identify and handle possible obstacles to the optimization (insufficient staff information or communication, inadequate hardware or software, etc)
- Modularize the company activities and consider how to optimize each module without sub-optimizing the whole system.
- Consider modelling/simulation/optimization and control methods. What are the input (people, capital, natural resources, return of investments issues, competitors, law, market demand). How much do they vary and why do they vary. What is the optimal set of input parameters? How do we maintain these optimal input parameters? Are they always the same?
- Consider continuous optimization and improvement. How should the new sets of optimal input parameters be efficiently found, as products and raw material change?

The optimization production criteria might be found within number of choices:

- Price
- Quality
- Possibility of easier broadening selection of articles
- Faster (better) deliveries
- Environmentally friendly products
- A combination of all or some above, etc.

Most of the optimization methods are using the major cost function with number of input parameters viewed as all factors controllable and uncontrollable, which affect the company activities.[6]

In food production and processing the optimization is constrained by legal procedures and policies, such as process traceability. Such systems as HACCP reflects criteria for food production and optimisation that exist in food legislation (temperature, content, and contaminant). Once a system is in place, it determines the criteria for working practises in the business such as quality control procedures or staff practises.

The continuous production is better for optimisation and automation of the process. By employing PLCs and other automated controls, we can reduce chances of error (thereby delays/ downtime) due to human intervention. This is due to the fact that most of the jobs are routine enough and can be easily automated. So there is a lot of scope for conveyors, elevators, feeders, etc for transporting raw materials, in-process materials etc in continuous process industries. Very often the IT systems armed with the genetic algorithms (GA) and multilayer perceptron[1] neural network (MLPNN[2]) are used for optimization production and distribution, as well as heuristic and metaheuristic algorithms.

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[1] Perceptron – type of artificial neural network invented in 1957 at the Cornell Aeronautical Laboratory by Frank Rosenblatt. It can be seen as the simplest kind of feedforward neural network: a linear classifier.

[2] MLPNN – Multi Layer Perceptron Neural Network. A kind of artificial neural network. Class of networks consists of multiple layers of computational units, usually

2 Optimization Methods

The ability to optimize or improve a process depends on ability to control it. The ability to control the process is dependent upon the access to reliable and valid measurements. A successful process optimization thus entails a strategic approach such as:

Measure => Control => Optimize

One of the advantages of batch production is the possibility of inexpensive production of a wide variety of final products even in small quantities. Production planning usually takes place in two stages.

In batch planning, the number and size of the individual batches to be processed are determined for each transformation step. The production of one batch using resources corresponds to one operation: Planning the allocation over-time of resources including employees, inventories, and processing units to the operations arising from batch planning. Thus, planning is sequencing for a short-term planning period. This is also referred to as batch scheduling. This can be done with various goals, such as minimizing the total production time (makespan) or minimizing overruns of prescribed deadlines for individual operations. The execution of operations takes place on multipurpose installations including processing units and substance-specific storage-facilities. Employees who may have various qualifications are needed to operate the processing units. At the beginning of an operation, the proper amount of input materials is consumed, and at the end of an operation the output materials that cannot be processed further immediately must be stored. In addition, it may be necessary in planning activities to take into account various production restrictions. For example:

- Individual substances may have a quarantine time or a shelf life time after which they may or must be processed further at the soonest or at the latest.
- A minimum and maximum inventory is specified for each storage facility and the inventory must remain between these two bounds.

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interconnected in a feed-forward way. Each neuron in one layer has directed connections to the neurons of the subsequent layer. In many applications the units of these networks apply a sigmoid function as an activation function.

- Concentration of primary production in a short period of the year: often, primary products are not available during the whole year to be processed.
- Furthermore, the total availability of processing units and employees as resources is always limited.
- Another restriction may be defined as being that many resources can be used only for certain operations. Thus, for example, certain operations may be carried out only by certain employees on certain processing units.
- Another particular production aspect may consist of the fact that processing units must be set up between the execution of individual operations. Such a setup may include cleaning, for example. The duration of this setup may depend on the sequence in which the operations are carried out. With regard to employees, it must be taken into account that the number of employees may vary over time. Thus, for example, fewer employees are usually available during a night shift than during a day shift.
- In addition, operations may often be carried out in several ways, which may differ with regard to the resources used as well as the duration of the operation. Breaks may be specified for the processing units and employees as resources, so they are not available for carrying out operations during these breaks. Many operations may be interrupted at the beginning of such a break and must then be resumed immediately after the break. However, there are also operations that must not be interrupted at all.
- Complex correlations between process variables might make it necessary to consider many parameters simultaneously during process adjustments.
- Several process levels might exist, all with different optimal variable settings.
- Changes in raw material and process conditions require continuous adjustments of variable settings.
- Several quality parameters might need to be optimized simultaneously.

The goal of batch production optimization is to establish a plan, i.e., a selection of resources as well as a start time and a completion time for all operations in such a way that all the production restrictions are met. Partial aspects of batch production that are taken into account in planning can be represented (modeled) as a resource-constrained project of the type "multimode resource-constrained project scheduling problem with minimum and maximum time lags." Such a project consists of a set of activities which use renewable resources during their execution, between whose start times prescribed minimum and maximum time lags are to be observed and which must be carried out in one of several alternative modes. Each activity in this type of model corresponds to one operation, i.e., production of one batch. Shelf life times and quarantine times for products are modeled by means of minimum and maximum time lags between the respective activities. A set of renewable resources is available for carrying out the activities. A renewable resource would be, for example, a group of employees having the same qualifications or a group of identical processing units that do not have to be set up. The available capacity of a renewable resource is constant over time and corresponds to the number of employees or processing units by which they are modeled. Each activity uses during its execution as many units of the individual renewable resources as required by the respective employees or processing units for execution of the corresponding activity. If fewer employees are available in a period of time (e.g., during a night shift), this is modeled by additional fictitious activities that are fixed in time by minimum and maximum time lags and take up the difference between the maximum availability and the actual availability. A mode is defined for each possible selection of resources for an operation. Thus, the demand on renewable resources and the duration of the activities depend on the mode selected.

A feasible solution to such a project planning problem will assign exactly one mode and one start time to each activity, so that the minimum and maximum time lags between operations are observed and at no time is more capacity of a renewable resource required than is available. A feasible solution is regarded as optimal if there is no feasible solution to the project planning problem whereby the project is completed sooner.

A comprehensive and successful process optimization should thus compress:

- A dynamic optimization goal, that should consist of a cost efficient weighted combination of the interesting process outputs (production variations, production cost, product qualities and emission levels). A dynamic goal also means that it should be possible to automatically change the optimization goal as the process levels change.
- Handling of long term process changes with possibilities to continuously carry out optimization regardless of seasonal changes or changes in raw material. [3]

3 Influence of production optimization on Supply Chains

Integration allows optimized decision making, and lets companies manage constraints in line with business priorities. It consists of establishing an integrated plan for the supply chain's response to anticipated demand and actual customer orders. Some variable factors influencing this integration could be: the company's supply chain operating model, the complexity of the supply chain or the characteristics of the company's supply chain.

It is known that good communication in supply chains has a good impact for production optimizations. When the manufacturer is early alarmed that there is a lack of products on shop shelf, he can earlier react and make activities to produce more of this product. On the other hand when his supplier early alarms that he is not able to supply him with raw materials or half products then again he has more time to react and find solution.

In this sense, when a part of the whole supply chain is optimized it has influence on the rest of it. An optimized production process has the potential to generate savings in the whole supply chain costs, and it is necessary to design the process which utilizes assets according to the business strategies.

Once a production process structure is identified, it is possible for example identify the most cost-effective inventory strategy that has its influence on the previous steps of the supply chain. In the same way, with an effective production process, it is possible to respond to customer demand in the most profitable way.

Some consequences of optimizing the production process in the supply chain are:

- Design and implement an optimal process to meet business objectives
- Analyze operating characteristics and performance of the entire supply chain
- Avoid inventory shortages
- Understand and analyze the supply chain cost
- Simultaneously consider fluctuating global customer demand and supplier material flows
- It is a previous step to: Enable fully integrated financial analysis; Enable multi-company, factory, distributor, and supplier planning; Enable multi-criteria planning: Cost, customer service, assets, inventories.

In short, consequences should be:

- Improving visibility across the supply chain;
- Improving the synchronization of supply to meet demand.

Food and beverage companies now offer more products to meet the changing demands of today's consumer. Product lines must be constantly adjusted to meet consumer demand. Integration, collaboration and access to timely, accurate information—from the field to the store—are all important issues for today's food and beverage companies.

Food processors, it means, the companies that prepare agricultural products for human consumption, operate in an extremely fast-paced environment. Accurate information throughout the entire production and demand flow is the key to ensuring the freshness and safety of products. Whether these companies sell direct to consumers, or through retail or food service establishments, customer perceptions are the key. Integration would consist on maximum speed and efficiency, ensuring product arrives fresh, customer orders are filled accurately, and having the necessary data to react quickly to change.

4 Optimization Criteria in production process

These are criteria on which the optimization should be set upon. Usually cost and time oriented criteria are applied. Producers also want to adjust their production to be best fixed in the whole supply chain and this can be a combination of more than just one criterion.

Some Criteria to optimize a process should be:

Costs of production – this is the most often used criteria for production optimization. Each manufacturer wants to produce their product in most effective and cheap way. It is often noticeable that the costs of design and the costs of production in its primary stage are usually very high. It is due to the fact that engineers will specify commonly used and safe, materials and processes rather than inexpensive, cost-efficient ones. This approach reduces the project's risk regarding technical issues, but on the other hand it increases the risk of financial failure caused by the high costs of production. Good organisations develop and review checklists to review product designs.

Quality of final products – in this case, product quality is the most important factor of activities related to production optimization. They are more important than the low costs or times. Here manufacturer often avoids using cost efficient raw-materials and ingredients. The production with this is carefully planned in time.

Lead time – time from ordering the products from the end customer to the final product. In industry lead time reduction is an important part of lean manufacturing management philosophy focusing on reduction of 7 wastes: Over-production, Waiting-time, Transportation, Over-processing, Inventory, Motion and Scrap.

Production risk – for some manufactures the risk can have most important meaning so they would not choose cheaper suppliers, but rather those who they know well and whose products are good enough for their production.

The production optimization can be set upon one of those criteria or it can be a combination of few or all of them. It depends on market situation, supply chain requirements and resources of the company. Optimization is often done due to the operation in the whole Supply Chain. The main principals for the optimization are:

- Perfect first time quality – quest for zero defects, revealing and solving problems at the source
- Waste minimisation - eliminating all activities that do not add value and safety nets. Maximise use of scarce resources (capital, people, land)
- Continuous improvement – reducing costs, improving quality, increasing productivity and information sharing
- Pull processing: products are pulled from the customer end, not pushed from the production end.
- Flexibility – producing different mixes or greater diversity of products quickly, without sacrificing efficiency at lower volumes of production
- Building and maintaining a long term relationships with suppliers through collaborative risk sharing, cost sharing and information sharing arrangements.

The computer Aided Production Engineering (CAPE) systems are designed to help in production optimization. They often offer special modules for Designs for experiments (DOF) and Simulated Analysis (SA). Where managers may simulate and do some experiments in the system before they will do it on life production. The important thing in those systems is support the communication in the Supply Chain. Program should be able to update database with data from shop floor monitoring system.

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