# Schedule process modelling of a "wood processing SME" based on IEC/EN 62264 standard

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***Abstract**: The purpose of the research is to present a solution to production planning optimization problems, in cases of short-term customer orders and variable production load. The main reasons for the emergence of the task are the introduction of SMEs to unregulated electricity market and the increasing price of electricity due to the imposition of additional components in the formation of the price.The lack of traditional market and the small number of regular customers of SMEs make it difficult to forecast electricity consumption, and therefor impractical to request electricity for long-term periods of time. A possible solution related to the implementation of operational management systems, which, through the introduction of standard models, will enable the implementation of optimization algorithms for production planning.*

***Keywords**: MODEL DRIVEN DEVELOPMENT, IEC/EN 62264, MODELLING, SCHEDULE PROCESS*

## 1. Introduction

The need to improve the performance of production systems, related to increasing the level of coordination and integration of all resources and production functions in order to achieve flexibility and higher competitiveness, causes a growing interest in planning methods. Short-term and detailed production planning can be defined as a decision-making process that answers the questions: how, where and when to produce. How it relates to the required resources, where - to the allocation of each operation to a separate apparatus or machine, and when to predicting the start and end time of each operation. The most important resources are equipment, labour (personnel), raw materials, electricity, production or warehouse space, required capital, etc. The optimal distribution of resources leads to a shortening of production time, and hence to a reduction of production costs, which increases the competitiveness of production. In short-term, detailed planning, the focus is on satisfying the customer's requirements or completing the necessary tasks in the shortest possible time.

Optimal planning of production operations is part of the task of short-term, detailed planning and is a process of allocating available production resources to perform certain production tasks and determining the sequence and time parameters for performing this work. The manufacturing operations themselves are defined in the product design stage. Regardless of the many efforts to tackle the task of optimal planning of operations, the variety of tasks in the field and their high dimensionality cannot be solved by universal means. In recent years, there has been an effort to use the results obtained in the field of formal verification and more precisely from solving the problem of model checking.

The main goal of the research, presented in this paper, is to propose a solution for the process planning task in a "Wood Processing SME", based on IEC\EN 622264 standard.

The paper is structured in 4 parts. After the introduction, in Part 2, a short analysis of the optimization methods for optimal process scheduling is done, in Part 3 a short overview of proposed techniques is done and in Part 4 the case study is presented. At the end some conclusions are made.

## 2. Short analysis of the optimization methods for optimal process scheduling

Production operations planning is an optimization task that requires the definition of one or more objective functions. Typical objective functions used in the field of manufacturing systems are:

- Number of orders fulfilled per unit of time (throughput).
- Number of unfinished orders (work-in-process inventory).
- Duration of order execution (lead time, mean order flow time).
- Difference between the completion time of the order execution and the execution time (mean order tardiness). If this difference is negative, it is assumed equal to 0.
- Minimization of the execution time of all orders (makespan), etc.

The main difficulty in the field of optimal planning of production operations is that there is a wide variety of tasks that prevent the development of a universal method for its solution. Different perspectives on the task of optimal planning lead to different approaches to its solution, systematised and presented in Fig.1. The traditional perspective in the academic world is static and deterministic, which has led to the development of numerous algorithms for off-line optimal planning. However, these methods, as well as those of deterministic dynamic programming and static stochastic planning, are inappropriate for the case under consideration, as they inadequately reflect the real aspects of the task. Reactive optimal planning algorithms accounting for disturbances in a dynamic environment are methods that embrace both the dynamic and stochastic nature of the optimal planning task. However, most reactive optimal planning methods do not predict the stochastic effects, but only react to them. Only proactive planning takes into account the risk of disruption. All methods listed so far are algorithmic. An alternative approach for many of the tasks can be structural solutions, which are called optimal planning architectures. They focus more on the practical aspects of the optimal planning task, such as software reusability, and are called optimal planning environments.

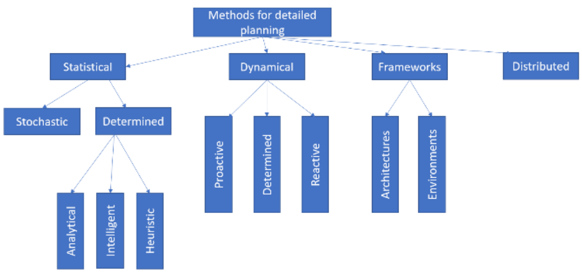


***Fig. 1:** Methods classification for detailed planning*

## 3. Short overview of proposed techniques

Manufacturing Operations Management systems (MOM) are mainly applied for real-time visual representation and control of production processes they interconnect the business information systems with the manufacturing and are middleware of the pyramid for automation [1].

### *3.1. IEC/EN 62264 standard*

Based on ANSI/ISA 95, the international standard IEC/EN 62264 is enterprise-control systems integrational standard. IEC/EN 62264 involves UML models and objects to solve the data inconsistency for transferring and aggregating data between different data levels [2]. It is separated on five main parts: models and terminology [3], objects and attributes for integration of enterprise-control system [4], activity models of manufacturing operations management [5], object models attributes for integration of manufacturing operations [6], and business to manufacturing transactions [7]. Through providing standard models and terminology the standard supports the development and usage of systems for manufacturing operational management.

According to IEC/EN 62264 the operations in manufacturing are separated on several levels (Fig. 2). The actual production is on Level 0; Level 1 is for detecting and control of the production processes; Level 2 is for supervising the production process and its time frame is measured in hours and minutes; LeveL 3 is for control of manufacturing operations through workflow control of production and optimizations of the processes, the time frame is measured in shifts; Level 4 is for developing the operational scheduling including actual production, shipping, etc., the time frame is measured in weeks/days [8].

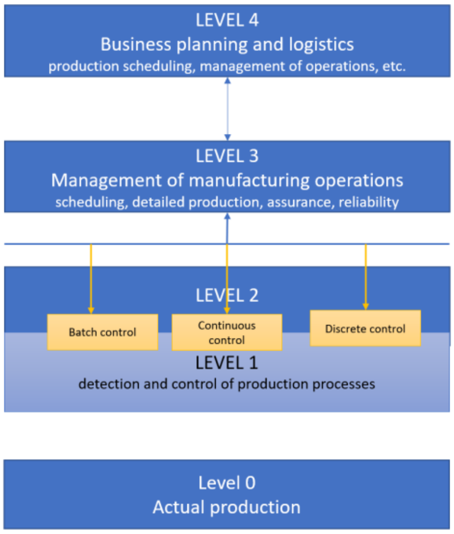


***Fig. 2:*** *IEC\EN 62264 production process hierarchy [8]*

According to the standard the activities in management of manufacturing operations can be separated into several areas for management of inventory, quality operations, maintenance operations and production operations. IEC/EN 62264 standard facilitates the separation of business process from production ones and segregates the exchanged information from business systems and specific manufacturing implementations. [1]

### *3.2. Model Driven Development and Model Driven Architecture*

Model-driven development (MDD) is a technique that moves model development on the front line instead of code first [9,10]. In [11] values symbolise models and variations map models to models and MDD is visualised as meta-programming architecture. One of the most promising realisations of MDD is Model Driven Architecture (MDA) of Object Managements Group (OMG). It ensures a conceptual framework for model development and transformation, which includes several types of models like Computation Independent Model (CIM), Platform Independent Model (PIM) and Platform Specific Model (PSM).

- **Conceptual Independent Model (CIM)** – is the domain model which previews the system expectations through a vocabulary. It excludes the specifications for implementing the system.
- **Platform Independent Model (PIM)** – helps with logical data modelling, specifies workflows and processes, defines dependencies. Creates a view of the system excluding the specifications required from the implementation.
- **Platform Specific Model (PSM)** – this model easE the code generation for specific platform by combining the details for the execution platform and PIM model.

### *3.3. Unified Modelling Language*

Unified Modelling Language serves to meet the requirements of Model Driven Architecture (MDA) and MDD. It is a modelling language used to create the solution specifications, documentation, design needed for the process of software development [12]. "Visual Paradigm" is a tool which supports UML, DevOps tools, SysML, etc. Models and their components are presented with UML [13]. UML 2.5 includes 15 diagrams separated in two main groups: Structural and Behaviour diagrams. Structural diagrams represent the static structure of the system and its elements on different levels of abstractions. Part of the structural diagrams are the class, object, deployment and component diagrams. Behaviour diagrams describe the dynamic behaviour of the system. These diagrams are used to describe the functionality of a software system, part of them are the use case and activity diagrams. Use case diagram describes the system operations from users' perspective through actors and cases (Fig. 3). Activity diagram represents the operational flows in a system.

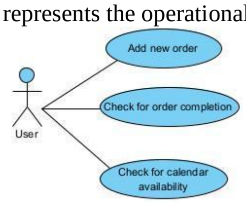


***Fig. 3:*** *Example of a Use Case diagram*

## *4. Case Study*

All resource models are already developed and described in [14].

### *4.1. Brief description of the "Wood Processing SME"*

Two main types of wood materials are processed - dry softwood and broad-rounded dry wood (oak) of different lengths and widths. One of the main processes that takes place is the process of grinding wooden boards, which is carried out on a wide belt grinder, consisting of a conveyor belt along which the sanding material is moved at a feed rate from 1 to 20 m/min (depending on the processed surface or the type of processed material) and a grinding speed in the range of 23 – 30 m/s. The maximum working width of the belt is 1200 mm. The grinding tool is an abrasive belt placed between two horizontal shafts, one of which is working and the other is winding. The purpose of sanding is to calibrate the exact size of the wooden board and the preparation for varnishing. Drive power is from 45 to 55 kW. The technological time for processing (sanding) 1 m2 of wood parts is as follows: 5 m/min - for coniferous, and 2.5 m/min - for broad-leaved. The waste raw material from this process is wood shavings, which are stored in a hopper, which has a capacity of 5 m3, which, according to the relative weight of the processed wood, means 550 kg/m3 softwood and 900 kg/m3 - hardwood (oak). When processing 1m2 of timber, about 2.2 kg of coniferous sawdust or 1.8 kg of broad-leaved sawdust are obtained.

Wood bran is used to produce pellets, which are highly efficient, clean, renewable energy leading to energy savings and reduced carbon emissions. Pelletizing is carried out with a press, which is a round, fixed matrix made of thick steel (about 30 mm.) and perforated with numerous holes, with a diameter corresponding to the diameter of the pellets. These holes fulfil the role of matrix(mold) in which the pellets are formed. The sawdust entering the press is pressed against the holes of the die by means of pressing devices (usually two to three rollers) which are self-propelled. Before entering the pellet press, the wood bran is moistened with water, after which they are fed into the press chamber of the pellet press. During the rotation of the pressing devices and under the pressure exerted by the toothed rollers, the material is pressed into the aversion of the matrix, during which the pellets are formed. In doing so, the friction heats up the die and the pellets leave the press very hot at around 95 °C. After they are cut, they go through a cooler and then they are packed. The productivity of the pellet press is 120 kg/h. The total power of the entire pelletizing plant is 15 Kw.

### *4.2. Defining the Operations Planning Task.*

The goal of the task is optimal planning of the operations in a “Wood Processing SME” described in point 4.1 and is expressed in determining an optimal time schedule of the operations performed by a woodworking wide belt grinder and the pelletizing press, utilising the waste material generated from the grinding machine and filling the hopper as an intermediate storage with limited capacity. The aim is to optimise the production process based on certain conditions and technological limitations. The technological limitations are as follows:

- Power supply limitation – due to energy limitation and insufficient electrical power supplying the furniture production, the wide belt grinding machine and the pelletizing plant cannot work at the same time.
- Hopper capacity limitation - when the hopper for collecting the waste material from the grinding machine is filled in the range of 80-95%, the pelletizing plant must be started.

There are *P* of wood grinding orders and *Q* of pellet orders. Each grinding order *l* is characterised by an arrival time (*al*) and a lead time ($d_l$) and includes one operation that is performed on one machine. Each pellet order *k* is characterised only by delivery time ($d_k$), involving 3 operations that are performed on three separate machines. The duration of all operations ($l$, $j_k$) is set. The first operation can start only after the order arrives. The following conditions should also be considered during planning:

- An operation can be executed only if all previous operations have been completed.
- Machines cannot execute more than one order at the same time.
- Once started, orders cannot be interrupted and replaced by others.

The goal of optimal planning of operations is to determine the time sequence of execution of orders, which ensures a minimum value of the time for execution of all orders, the characteristics of which are presented in Table 1 and Table 2.

| Monthly requests for grinding | | | | | | | |
|---|---|---|---|---|---|---|---|
| N | Date | Client | Type of wood material | Width [m] | Area [m$^2$] | Time [min ] | Delivery Time |
| 1 | 08:00<br>15.05 | Bulter | Coniferous | 0.28<br>0.48 | 68<br>192 | 128 | 13:00,<br>16.05 |
| 2 | 10:00<br>15.05. | Euromebel | Coniferous | 0.28<br>0.48 | 162<br>284 | 234 | 17:00<br>15.05 |
| 3 | 08:00<br>16.05. | Cotzevi | Coniferous | 0.28<br>0.48 | 29<br>98 | 62 | 17:00<br>16.05 |
| 4 | 09:00<br>16.05. | Sankevi | Deciduous | 0.28<br>0.48 | 18<br>48 | 65 | 15:00,<br>16.05 |

***Table 1:*** *List of orders for grinding of wood material*

| Monthly requests for pellets | | | | | |
|---|---|---|---|---|---|
| N | Date | Client | Quantity [kg] | Time [min] | Delivery time |
| 1 | 10:00<br>15.05 | A.N.N. 2 | 2000 | 1000 | 17:00,<br>16.05. |
| 2 | 14:00<br>15.05 | ARNI | 3000 | 1500 | 15:00,<br>17.05. |
| 3 | 12:00<br>16.05 | Kos Hol | 1000 | 500 | 11:00,<br>17.05. |
| 4 | 14:00<br>16.05 | Hol Les | 6000 | 3000 | 13:00,<br>18.05. |

***Table 2:*** *List of orders for pellets*

### *4.3. Models based on IEC/EN 62264*

For the aim of the task an activity diagram is developed based on IEC/EN 62264 (Fig. 4). It includes two group elements: “Infinite Planning” and “Fine Capacity Scheduling”. “Infinite Planning” includes the processes “Create Work Order”, which includes “Create Material Requirements”, “Create Personnel Requirements”, “Create Equipment Requirements” and “Create Physical Assets Requirements”, and “Calculate Lead Time”. “Finite Capacity Scheduling” includes “Calculate Dependencies”, “Check Calendar Availability”, which leads to the need of “Reserve Material”, “Reserve Personnel”, “Reserve Equipment”, “Reserve Physical Assets”, after all of the above are finalised only then the process can continue with “Reserve Capacity” and finalise the order.

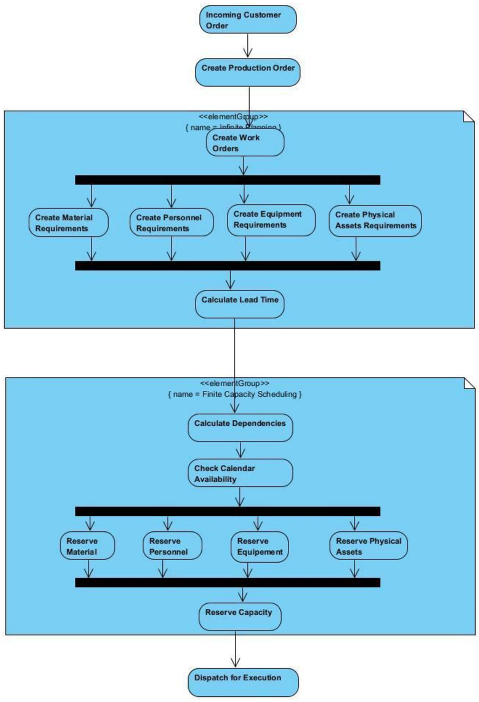


***Fig. 4:*** *Proposed activity diagram*

## *Conclusions*

The proposed approach for optimal planning of production operations using IEC\EN 62264 standard has the unique advantage of solving the task in real time and guaranteeing a quick response of the system in the conditions of changes in the technological structure and changes to the production program. Successfully solving the task of optimal planning of operations will allow more effective energy cost planning and construction of an efficient operational production management system that monitors pellet orders and starts the pelletizing machine when a certain amount of waste biomass is stored in the hopper for storage generated by the wide belt grinder. Pellet orders should be quantitatively tracked, and information should be given on the lead time for the ordered quantity of pellets.

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