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SIMULATION-BASED BUSINESS GAME FOR TEACHING METHODS IN LOGISTICS AND PRODUCTION

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ABSTRACT

Uncertainty in planning tasks such as processing times, set-up times, customer required lead times, due dates, time to failure, time to repair and the complexity in terms of product variety, outsourcing, short lead times, low inventory levels, low costs and high utilization are major hurdles for planning logistics and production processes. This paper introduces a simulation-based business game for methods in planning logistics and production processes. Basic methods such as material requirement planning (MRP), Constant work in progress (Conwip), Kanban, reorder policies, dispatching rules, basic demand forecasting methods and master production schedule (MPS) are implemented in the game. Due to the generic environment additional methods can be implemented efficiently. The midterm planning concept sales and operations planning (S&OP) is implemented as well, where the gamers have to act as managers responsible for purchasing, production, sales and finance. Their target is to identify sales and production volumes for the next planning periods.

1 INTRODUCTION

Many industries are facing strong global competition because time to market decreases and customers require fast deliveries of a variety of products provided with appropriate quality. This is leading to an extraordinary increase of the complexity in logistics planning (Craighead et al. 2007; Svensson 2000). Information systems such as enterprise resource systems or supply chain planning systems support the operator in the planning of business processes (Olhager 2013). Many different parameters have to be configured well in such systems in order to benefit from those systems (e.g. lot size, planned lead time and safety stock for each material when using MRP or reorder point and lot size when using a reorder policy) (Hopp and Spearman 2008).

Due to the progressive digitalization based on initiatives such as industry 4.0, digital factory, physical internet, internet of things and cyber physical networks, however, more and more valid data is available along the whole supply chain (Hübl et al. 2016; Montreuil 2011; Xiao et al. 2010). This data can be used to reduce the uncertainty in logistics processes.

Production engineers and their managers need to clearly understand the methods applied in their information systems. In the framework of a German-Austrian transnational research project of the European Territorial Cooperation Funding, a logistics laboratory called “LogLab” is currently designed and implemented to provide a sound means for understanding, enhancing and refining the processes relevant to logistics planning. The intention is to support lectures at the university level by providing hands-on training to teach entrepreneurial thinking and strategic decision support capabilities for logistics planning. To better understand the complex interrelations, simulation along with innovative didactical training concepts is the method of choice and represents the core of the LogLab.

2 LITERATURE REVIEW

2.1 Planning in Logistics and Production

Hierarchical production planning (Hax and Meal 1975) and the Manufacturing Resource Planning (MRPII) (Wight 1984) are still state of the art for complex planning tasks in production and logistics. The MRP algorithm (Orlicky 1975) which is part of MRPII concept as well as enterprise relation systems (ERP) or supply chain planning systems, is still in use in many information systems such as SAP and MS Navision. State of the art reviews on hierarchical production planning are conducted by Fleischmann et al. (2005), Meyr (2004), Missbauer and Uzsoy (2011) and Meyr (2004). The Supply Chain Planning Matrix (Meyr 2004; Rohde et al. 2000) classifies planning tasks according to procurement, production, distribution and sales, and includes the hierarchical planning levels from long term to short term planning. Logistics and production planning have to deal with three types of uncertainty (Graves 2011):

1. Uncertainty in demand forecast: production plans are in most cases based on demand forecasts, which differ from the customer requested demand;
2. Uncertainty in external supply processes: production plans results in purchase orders which might have uncertain delivery dates and volumes; and
3. Uncertainty in internal supply processes: completion time and volume of the internal manufacturing might also have uncertainty.

Each planning method has its own parameters and it is essential to use optimal parameter settings to avoid wasting resources. Fawcett and Cooper (1998) identified that firms are trying to manage the tradeoff between cost and customer service. To influence logistical performance, decisions for the right production planning and control (PPC) strategy, parameterization of selected PPC and capacity investment have to be defined.

In addition to the basic MRP (parameters lot size, planned lead times and safety stock per item), there are also parameters like planning period or amount of MRP runs per period influencing the performance of the production system (Hopp and Spearman 2008; Jodlbauer 2016). Kanban parameters are lot size and amount of Kanban containers per item (Ohno 1988). Conwip uses a work-ahead window and a parameter regulating the Work in Progress (WIP) (Spearman et al. 1990). Capacity setting can require a lot of information such as future demand and uncertainties in the production process. Different methods are compared in Altendorfer et al. (2014). Besides the mentioned quantitative methods also qualitative methods such as sales and operations planning (Proud 2007) are used in logistics and production planning. Reorder policies have at least a reorder point and a lot size as parameters (Hopp and Spearman 2008; Jodlbauer 2016). Jodlbauer and Huber (2008) and Huang et al. (1998) compare the performance of different production planning methods. In Hübl et al. (2013) the influence of dispatching rules on the production lead time is discussed. Different forecast methods and their parameters are described in Box et al. (2008).

Since logistics and production planning have to deal with many different parameters, variables and stochastic effects, simulation in combination with optimization is used in recent literature (Abdul-Kader and Gharbi 2002; Felberbauer et al. 2012; Gilland 2002; Huang et al. 1998; Hübl et al. 2011; Kim and Kim 1994; Kutanoglu and Sabuncuoglu 1999; Sun et al. 2009) to identify optimal parameters and methods for production planning.

Information systems support humans to overcome the hurdles of uncertainty and handle the complexity. Therefore, it is important to understand the concepts implemented in information systems in detail.

2.2 Didactic Concept

The mentioned challenges to the field of logistics planning are also challenging the pace in which educational concepts must evolve. Distance-learning environments as well as simulation-based gamification represent methods that are able to enhance todays education in the field of logistics.

Cimino et al. (2010) compares different simulation frameworks for supply chain modeling. Fu et al. (2005) and Fu (2002) analyzes simulation-based optimization frameworks. Frameworks like Hübl et al. (2011) help to optimize real world problems in production planning in detail. On the one hand, improved parameters for planning methods such as MRP, Kanban, Conwip, reorder policies and Theory of Constraints (TOC) can be identified. On the other hand, this framework allows medium term capacity setting of workforce and equipment based on annual working times, skills, availability of tools and equipment. LLamasoft for instance developed a tool for supply chain network planning.

The added value of simulation-based games in education is widely accepted in the literature. According to Da Rocha Seixas et al. (2016) the use of gamification techniques is able to improve the engagement of young students. Alcivar and Abad (2016) proved the contribution to quality of ERP-system trainings by gamification approaches. They found that users trained by gamified systems perform better than those without gamified systems. Harteveld (2011) examines the fundamentals of designing any game with a serious purpose.

Pasin and Giroux (2011) have analyzed the impact of simulation gaming on operation management education. The results of the study show that although simple decision-making skills can be acquired with traditional teaching methods, simulation games are more effective when students have to develop decision-making abilities for managing complex and dynamic situations (Pasin and Giroux 2011). Camaj et al. (2015) focused at the use of a simulation tool in the teaching of modeling transport processes. This area demands of logical thinking and imagination. They see importance in an active use of simulation in the teaching of modeling transport processes to force the understanding of the synergistic activities. Potkonjak et al. (2016) pointed out the importance of laboratory exercises due to the fact that distance learning has become more widely used in teaching. They focused on concepts which offer some advantages over remotely controlled real labs. A need of new concepts as part of learning about science and technology, through to supporting more constructive (and collaborative) education and training activities, is seen (Potkonjak et al. 2016).

The business games presented in Jodlbauer and Gmainer (2006) allow students to focus on the parameter setting of the basic production planning methods MRP, Kanban and Conwip and their effects on service level, work in progress (WIP), finished goods inventory (FGI) and utilization. The famous beer game developed in the 1960s at MIT has been implemented into a digital version and has been adapted in the past decades (Jacobs 2000).

Uncertainty and complexity of logistics and production planning combined with inherent need of distance-learning environments due to the sparsely-populated peripheral areas of Upper Austria und Bavaria represents the main motivation for the development of a simulation-based gamification concept for educating logistics planning processes. This concept is not focusing only on one method or effect such as the beer game; instead, many kinds of logistics and production planning methods are addressed and can be combined as needed in a virtual enterprise environment.

3 MODEL DESCRIPTION

The intention of this paper is to combine digital and analogue options to better impart logistics knowledge to students. Dry theory that is very abstract especially to those with no work experience so far is turned into a tangible process that illustrates the interferences and magnitude of influencing factors in logistics planning.

A simulation model was developed implementing the main known planning methods (e.g., MRP, Kanban, Conwip and MPS). On the one hand it visualizes the resulting flows of material and processing steps in the shop floor and on the other hand, the key performance indicators (KPIs) to evaluate the various planning methods are tracked and illustrated in numbers and figures for further discussion. As training environment a fictitious company *LogLabSim GmbH* from metal processing industry whose production and shop floor structure (see an excerpt of the shop floor 3D visualization in **Error! Reference source not found.**) is representative for the German – Austrian home region is developed.

The idea behind the combined approach is to put the future logistics planners (i.e., the students) into a double role. First, they have the task to perform the logistics planning by defining the various input parameters (e.g., planned lead times, lot-size or safety stock) that can be set depending of the planning method chosen. Second, they will be challenged to become part of the shop floor themselves by taking control of one of the machines of the LogLabSim GmbH production. In other words, the simulation starts with all the input parameters being set by the students in advance. In addition, the simulation system will be fed with a prepared set of customer orders over a specific period of time. The production planning and production control is then completely managed by the simulation. The single machines (each representing one processing step to create the final product and thus satisfying the customer orders), however, will be controlled by the students. This enables the students to perceive the consequences of their planning in the shop floor. In a poorly configured production, there may arise for example long order queues in front of the machines or the machines are forced to wait for missing material resulting in bad overall performance measured by KPIs. The effects of the students' decisions will be automatically visualized by the simulation. That is, predefined key performance indicators (KPIs) can be tracked and while letting the students experience the shop floor situation themselves, the overall performance can be objectively assessed and discussed in a debriefing session.

3.1 Simulation Framework

Based on a generic framework presented in Hübl et al. (2011), Altendorfer et al. (2013) and Felberbauer et al. (2012) a simulation framework for teaching planning methods in logistics and production planning for educational purpose has been designed. Master data (e.g., bill of material (BOM), routings, planning methods and their parameters) and transaction data (distributions and their parameters for processing times, set-up times, replacement times, customer required lead times, time to failure and time to repair) are stored in a database. This avoids throw-away solutions for each of the scenarios needed (Thompson 1994). The data from the database is imported into the simulation framework and the shop floor as well as the related planning process.

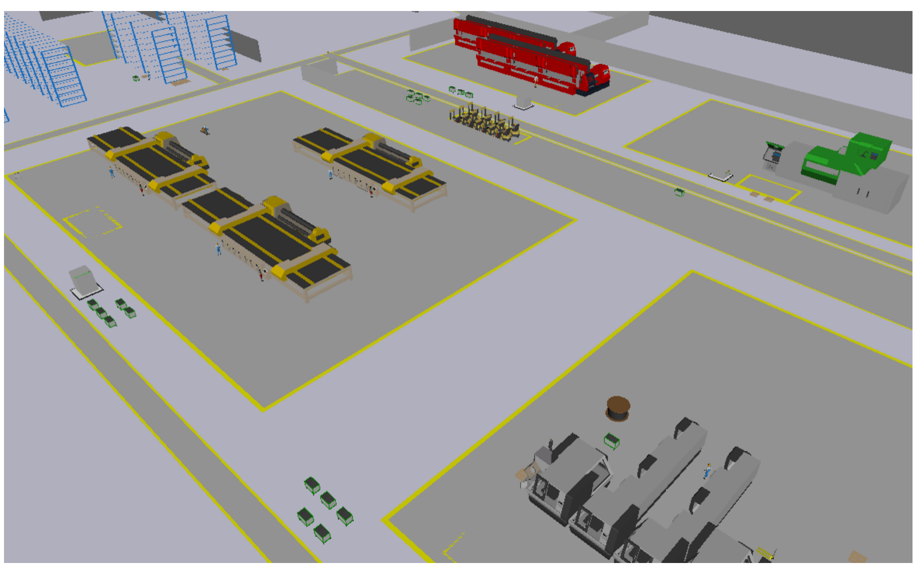

Figure 1: Excerpt of shop floor in 3D visualization.

The specific LogLabSim GmbH characteristics such as the BOM, the shop floor layout as well as the customer behavior are stored in a database and imported by the simulation at runtime. Figure 2 illustrates an example how the BOM looks for two final products – the metal cases F1beige and F2beige. Actually, the LogLabSim GmbH offers four more final products, which only differ in color (i.e., F1black and F2black as well as F1blue and F2blue).

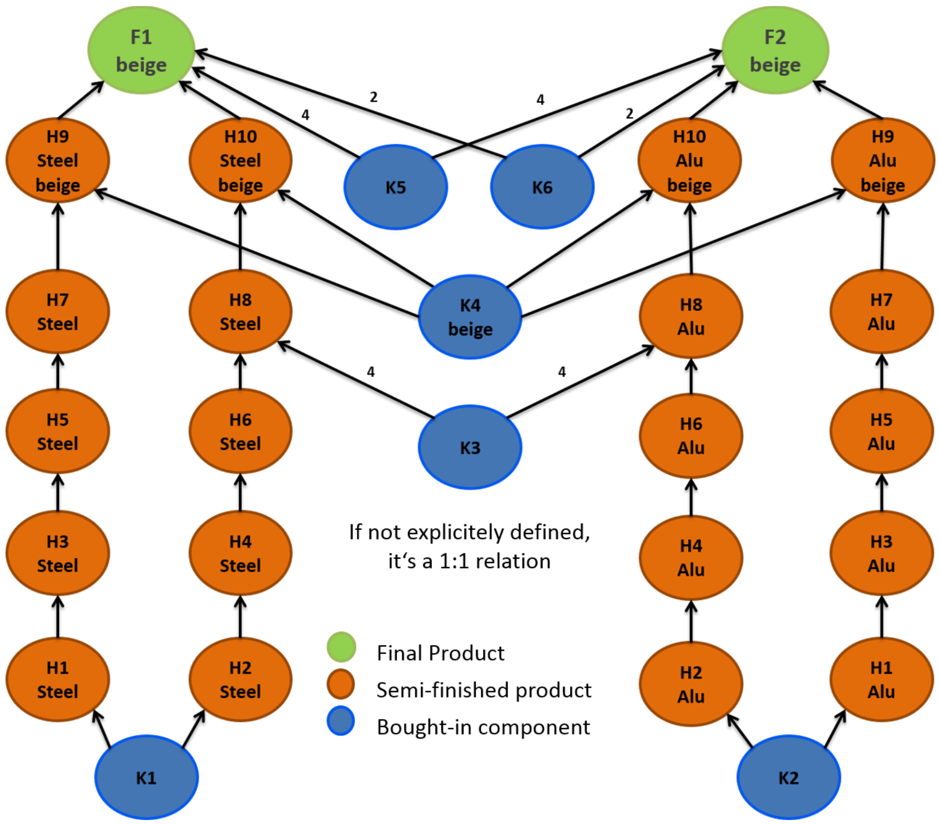

Figure 2: Bill of material.

For the simulation we realized a modular generic approach with currently 5 main modules (as shown in grey and blue in in Figure 3) that will be explained in the following.

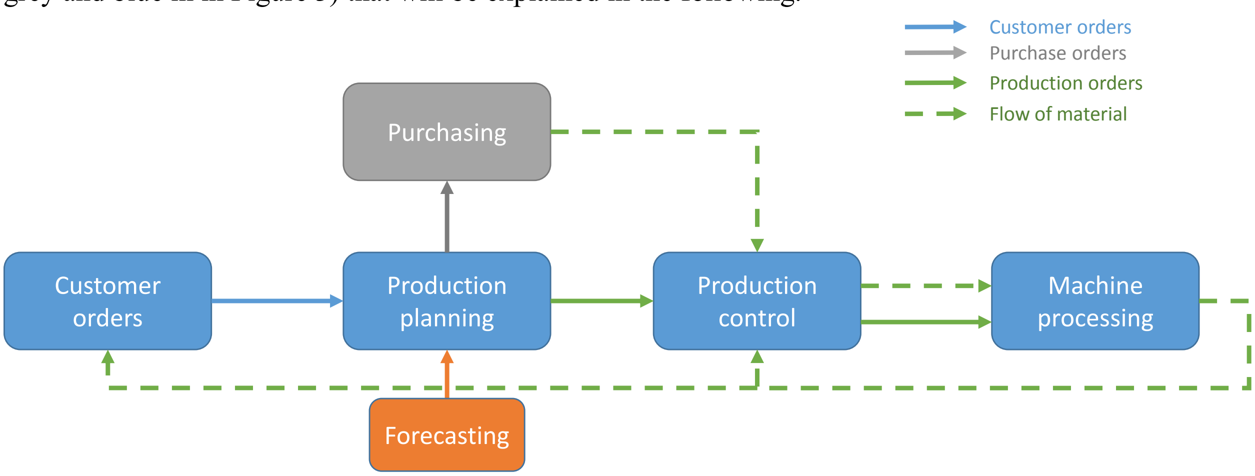

Figure 3: Generic modular approach.

The module “Customer orders” generates the customer orders, which are used to pull the finished items from the FGI placed in the module “Production control”. The customer orders are also the input for “Production planning”. The production planning generates production orders or purchase orders based on the hierarchical MRPII approach (Hopp and Spearman 2008) whereby different planning methods such as MRP, Conwip or Kanban are implemented. The planning methods and their parameters can be defined for every single product in the underlying input database describing the company’s production structure. Moreover, the planning module consists of a forecasting sub module for predicting future sales by the use of different methods such as exponential smoothing, moving average or ARIMA (autoregressive integrated moving average).

The purchase orders from the production planning module will be processed in the module “Purchasing” according to the desired purchase strategy (e.g. order cycle system) which again can be defined for every single bought-in component in the input database. Delivery times can be specified using stochastic distributions.

The “Production control” module has three input streams: firstly, it receives the bought-in components (raw material), secondly, it takes all the production orders generated by the planning module and thirdly, it maintains all the products manufactured by the existing machines. The execution of orders may follow different strategies: In some cases it might be reasonable to ignore a given production order until all material components needed to satisfy this production order (self-processed as well as bought-in items) are available. In other cases, it makes sense to reserve the required components that are already in stock. So that processing can start immediately after the last missing component arrives (either from the purchasing module or – in case of a required semi-finished component – from the machine processing module). Since the production control module administrates all components (raw material, semi-finished products and final products) in stock, it contains a respective inventory data structure (that may be pre-filled with an initial inventory stock at simulation beginning) and hosts the respective storage administration. The latter allows the implementation of several storages (e.g. a main storage as well as interim storages at the various machines) and takes care that new items can only be stored up to given maximum capacity. A forthcoming storage overrun may then result in respective production stops.

If all required components for a given production order are available, machine processing can start in the module “Machine processing”. The execution steps at which machine a certain item will be produced depends on the routing information described in the company’s input data. There may be several instances of the same machine type, so several production orders can, of course, be processed in parallel. Every single machine group has its own queue, where production orders and the responding material are executed according to a predefined dispatching rule (FIFO in the easiest case, although different rules are available). Manufacturing is a time-consuming process, the underlying stochastic set-up times and processing times are, again, defined in the company specific input database. For each single machine, the failure times and the repair times may also be specified. Whenever a new item is manufactured, it will go back to production control and be added to inventory.

Alternatively, machines can be controlled by the gamers. Therefore, the simulation model is implanted into a client-server application where mobile devices such as smart phones or tablets represent a certain machine. The queue of released production orders is displayed on these devices and the gamers can press a start or stop button to start or stop the machine. This configuration allows to demonstrate the production process itself and the gamers immediately can comprehend idle time of a machine (e.g. waiting for the material, waiting for an order). If there are not enough gamers participating then the simulation model will control machines automatically.

3.2 Didactic Concept

The core element of the didactic concept is the above described simulation-based business game in which the gamers are able to set parameters of the observed methods such as lot size and number of Kanban containers for Kanban, lot size and reorder point for a reorder policy or planned lead times, lot size and safety stock for a MRP setting. The methods applied in the business game are presented in the first column of the following tables in this section.

2D and 3D animation of the shop floor (see **Error! Reference source not found.**) are available for all methods. The moderator always has the ability to switch between the different views (different camera views such as a random forklift, stock in front of machine groups, main stock, 2D, 3D) and charts of the logistic key figures. Moreover, the moderator can always adjust the speed of the simulation. The delivery to the customer or the supply of raw material is not considered and form the system boundaries.

For pedagogical reasons the moderator has two possibilities for the control of the machines. The simulation model can either start the production based on the processing times defined in the database or a user controlled operation is possible. For the user controlled operation the gamers press start/stop on a button on a mobile device to start or stop the machine, if a production order with its available sub material has reached the starting time. The production order is displayed on the mobile device so that the gamer has all the necessary information for production. In the fictitious company environment of the LogLabSim Gmbh, boxes of steel sheets are produced on six consecutive machines. In the user controlled setting, the underlying production steps are imitated accordingly: cutting (box and its cover plate are cut with scissors out of a slip of paper), bending (the box plate is bent), drilling (eight holes are stamped with a hole puncher into the cover plate and box), painting (two rectangles on the top of the cover plated are painted with a highlighter), press (nuts are pressed into the box and therefore the gamers have to stick four paper reinforcement rings onto the holes) and assembling (the box, cover plate and two wooden side plates are assembled and screwed with four screws). If there are not enough gamers then any one of these machines can also be controlled by the simulation model. For the user controlled manufacturing process in the interactive simulation environment the duration of one game where one parameter set is simulated is set to approximately 15 minutes. For the automatic (closed simulation) mode the results of the key figures pop up as fast as possible (depending on the simulation hardware).

The last column in Table 1 lists the parameters which can be influenced by the gamers for each method. Basically the gamers have the task to increase the logistics performance (tardiness, service level, average inventory level of WIP and FGI, production lead time), by changing the parameters of the observed method. The methods reorder policy, MRP, Conwip, Kanban and dispatching rules are implemented as a method instruction only. Therefore, no process optimizations (the gamers should need for every repetition of their own production task the same time for all games) are assumed to ensure that the effects on the key performance indicators originate only from changing the parameters. The parameters of those methods are set to result in a bad performance for the first run. After the first run, the gamers have to discuss changing the parameters, which is guided by a moderator (guideline for teaching the effects of each method have been provided). Having finalized the parameters the game will be repeated with the new setting. The moderator guides the group to demonstrate the interesting cases of the methods. The moderator has to steer the groups carefully not to mix up effects. E.g., in the case of MRP, the business game can illustrate that just cutting the lot size in half does not result in a 50% inventory reduction. Therefore also the planned lead times have to be adjusted (assuming 100% service level).

Basically, the necessary raw materials are always available for the method instructions of MRP, Kanban, Conwip and Dispatching rules (see Table 1 – see next page). For the reorder policy it depends if the reorder policy is just focusing on purchasing or whether the reorder policy is also used for production planning. For the complex methods such as forecasting methods, MPS and S&OP, fluctuations in the purchasing process are available in terms of lead time fluctuations and amount fluctuations.

In teaching the various logistics and production planning methods, the same predefined orders are used in order to allow a comparison of the methods (see
Table **2** – see next page). After having studied/played all five methods in single rounds of the game, the gamers can compare the logistics key figures for each method with their best parameter sets. For the five methods reorder policy, MRP, Conwip, Kanban and dispatching rules an MTO (Make-To-Order) environment is assumed so that the gamers can again identify the changes of the method's parameters on

the logistics key figures. So for example no forecast effects on releasing production orders affects these settings.

Table 1: Supplier assumptions and didactic support.

Methods	Supplier		Didactic support			
	Lead time	Amount fluctuation	Visualisation	Controll of machines	Game time	Parameters gamers
Reorder policy	No / stochastic	No / stochastic	2D, 3D, Key figures	User controll / Simulation modell	15 min/as fast as possible	Lot-sizes, Reorder points, Reorder cycles
MRP	No	No	2D, 3D, Key figures	User controll / Simulation modell	15 min/as fast as possible	Planned lead times, Lot-sizes, Safety stocks
Conwip	No	No	2D, 3D, Key figures	User controll / Simulation modell	15 min/as fast as possible	Dispatching rules, Wipcap, WAW
Kanban	No	No	2D, 3D, Key figures	User controll / Simulation modell	15 min/as fast as possible	Lot-sizes, Number of containers
Dispatching rules	No	No	2D, 3D, Key figures	User controll / Simulation modell	15 min/as fast as possible	FIFO, EDD, SPT, Random, Least slack, Least slack per remaining operation
Forecasting methods	Stochastic	Stochastic	2D, 3D, Key figures	User controll / Simulation modell	As fast as possible	Arima, Holt-Winters, Moving average, Exponential smoothing
MPS	Stochastic	Stochastic	2D, 3D, Key figures	User controll / Simulation modell	As fast as possible	Time aggregation, Product aggregation
S&OP	Stochastic	Stochastic	2D, 3D, Key figures	User controll / Simulation modell	As fast as possible	Sales, Purchasing amount, Production plan, Overtime, Working shifts, Multi sourcing, Investment/deinvement in machinery

no means that raw material is always available

Table 2: Customer and production assumptions.

Methods	Production					
	Production strategy	Proessing times	Set-up times	Machine failure	BOM	Routing
Reorder policy	MTO	Predefined	No	No	Simple	Simple
MRP	MTO	Predefined	No	No	Simple	Simple
Conwip	MTO	Predefined	No	No	Simple	Simple
Kanban	MTO	Predefined	No	No	Simple	Simple
Dispatching rules	MTO	Predefined	No	No	Simple	Simple
Forecasting methods	MTS	Stochastic	Stochastic	Stochastic	Complex	Complex
MPS	MTS	Stochastic	Stochastic	Stochastic	Complex	Complex
S&OP	MTS	Stochastic	Stochastic	Stochastic	Extensive	Extensive

Methods	Customer		
	Order Amount	Cust. required lead time	Orders
Reorder policy	Predefined	Predefined	30
MRP	Predefined	Predefined	30
Conwip	Predefined	Predefined	30
Kanban	Predefined	Predefined	30
Dispatching rules	Predefined	Predefined	30
Forecasting methods	Stochastic	Stochastic	1000
MPS	Stochastic	Stochastic	1000
S&OP	Stochastic	Stochastic	5000

Predefined means that the value is stochastic but known in advance so that the szenarios are comapreable

For forecasting methods, MPS and S&OP a MTS (Make-To-Stock) environment is chosen so that the gamers can have the opportunity to produce stock during times when the customer demand is less than average production capacity. Sales and operations planning (S&OP) is an integrated planning process through which gamers continually achieve focus, alignment and synchronization among all functions of the organization. The S&OP includes an updated forecast that leads to a sales plan, production plan, inventory plan, customer lead time (backlog) plan, new product development plan, strategic initiative plan and resulting financial plan. In the beginning, the gamers are provided with a case study where transaction data (e.g. customer orders, processing times on each machine, set up time on each machine, failures and idle time on each machine and purchasing lead times) of the past three years are provided. For S&OP planning two situations are possible within this business game. On the one hand all gamers together try to act as a group to improve the company, whereby a high amount of customer orders (1,000 orders) and an extensive BOM and routing structure is applied. The target for this situation is to get the best out of the production system. On the other hand each gamer presents a different management function such as purchasing, production, logistics and sales. The gamer have in the beginning only knowledge of their department. The production manager for example has only information about processing times, set-up times, failure and idle time of the machines but no information about purchasing lead times, investment decisions, customer needs. They have to present their expectations in a board meeting and have to convince the CEO (moderator) for the sales, productions plans and investment for the next S&OP planning cycle. After entering the new figures the simulations model presents the deviation from plan figures to actual figures.

Attention has also been paid to a didactic learning concept. A web based platform has been developed where presentation and videos will support the learning effort of the gamers. Online pre-tests are included to examine the current skills. A guideline for teaching the effects for each methods has been prepared as well.

The simulation model has been validated as proposed in Kleijnen (1995) by checking the model behavior of the single-machine case with predefined customer orders and processing times to confirm the analytic results. Moreover, the different modules such as production planning, production control and machine processing (see Figure 3) and the planning methods such as MPS, MRP, Conwip, Kanban have also been validated for the production structure (see Figure 2) presented in this article by feeding the simulation system with predefined customer orders and forecast order over a period of time. Pretests of the lecture (production planning and control course at the undergraduate degree program Production and Management at the University of applied sciences Upper Austria) with voluntary students have shown that the simulation model increases their understanding of the used methods compared to the regular groups where this simulation teaching approach has not been applied for teaching.

4 RESULTS SUMMARY

With the objective in mind of creating a close to reality but workable business game supporting logistics lectures for bachelor and master programs at the University of Applied Sciences Upper Austria Campus Steyr and the Deggendorf Institute of Technology we decided to create a simulation-based case study model which will be finished at the end of 2018.

The generic database driven simulation model is embedded into a web interface, where different methods can be selected. Based on an underlying didactic concept the gamers have to adjust the parameters of the methods in order to achieve better key figures (KPIs).

By combining case study based lectures with approaches in gamification and simulation an innovative didactic concept was created. This setting is able to improve the quality of education in the field of logistics and production planning as shown by the students pretests. Further results for the improved learning by the use of the simulation framework can be gained in the next years when the simulation model will be an inherent part of the lecture.

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