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LEAN ENGINEERING FOR PLANNING SYSTEMS REDESIGN – STAFF PARTICIPATION BY SIMULATION

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ABSTRACT

Lean manufacturing aims at flexible and efficient manufacturing systems by reducing waste in all forms, such as, production of defective parts, excess inventory, unnecessary processing steps, and unnecessary movements of people or materials. Recent research stresses the need to include planning systems in a lean evaluation and redesign of manufacturing systems. Lean planning systems may contribute to a regular, customer focused flow of products. In line with these ideas we study the redesign of a complex planning system for a coffee manufacturing plant. We show how simulation may be used to facilitate the engineering process, by allowing for direct participation, and contributions of planners, managers, and domain experts. More in particular we discuss, and evaluate the use of a modeling framework for manufacturing simulation. It supports conceptual modeling by offering an architecture of high-level class descriptions of manufacturing elements and relationships for specifying simulation models.

1 INTRODUCTION

This article is motivated by a project on the redesign of a planning system for a coffee manufacturing plant. It presents an example of the way companies nowadays try to meet customers' demands, the competition, and their own performance standards, by redesigning their plants according to the lean manufacturing concept. Essentially, this concept aims at flexible and efficient manufacturing systems by reducing waste in all forms, such as, production of defective parts, excess inventory, unnecessary processing steps, and unnecessary movements of people or materials (Womack et al. 1990; Goldman et al. 1995).

Recent research stresses the need to include planning systems in a lean evaluation and redesign of manufacturing systems (Glenday 2006). An obvious reason to do so lies in the improvements to the underlying production systems. This forces an update in the planning model, in terms of relevant parameters of the production system. More important, however, are the contributions a lean planning system may make to a regular, customer focused flow of products. This implies a need to actively explore and implement opportunities for improving system performance, through the introduction of more advanced planning logic, a reorganization of the planning staff, and a tailoring of the infrastructure of supportive systems.

Essential characteristics of the project on the redesign of the planning system for the coffee manufacturing plant are: (1) complexity of both the production system, and the planning system, (2) multiple stakeholders (planners, managers), and domain experts, and (3) an active participation of all relevant parties in solution creation. Active stakeholder participation is in line with the lean manufacturing concept (Womack et al. 1990). It is supposed to contribute to validity, quality and credibility of solutions.

The project team decided that simulation should be adopted as a principal tool for decision support on the new planning system. Clearly, simulation may be a suitable tool for modeling and analysis of manufacturing systems. Realizing the potential of simulation in supporting a process of participative engineering of a planning system, however, sets some additional demands to its use (Van der Zee et al. 2008). Essentially, simulation should facilitate:

1. A joint overview among project team members, to support, and foster, group discussion.
2. Clear identification and visualization of all key decision variables.
3. Model understanding among all parties involved.
4. An incremental approach towards engineering.
5. A natural link between the modeled planning system and the planning organization.

These demands build on the notion of simulation boiling down to a human guided search for good quality solutions. The fact that multiple stakeholders are expected to join this search, sets high requirements on the common language (1-3), engineering approach (4) and the distinction of stakeholders' own roles (5). The demands set a starting point for conceptual modeling – being the precursor to model coding. From an engineering point of view conceptual models may act as an important platform – "the drawings" – for system design. Next, they influence the set up of the coded simulation model, which may serve as a test bed for evaluating alternative solutions for logic and performance.

In this article we study the way a modeling framework for manufacturing simulation (Van der Zee and Van der Vorst 2005; Van der Zee 2007) may facilitate conceptual modeling for participative engineering. The modeling framework offers a high-level class description of essential manufacturing elements and relationships, as well as their dynamics. This includes a clear definition of manufacturing planning and control, in terms of agents being responsible for decision jobs. Decision jobs steer activities of other agents, such as, for example, work stations or lower level decision makers. More in particular we relate the modeling framework to relevant activities in simulation methodology on conceptual modeling. Next, we illustrate, and evaluate the use of the modeling framework for conceptual modeling by its application for the project.

The remainder of this article is organized as follows. First we will review related literature, and state our research contributions (Section 2). Next, we describe the basics of our modeling framework, and relate it to simulation methodology (Section 3). In Section 4, we discuss the application of the modeling framework for the project. Finally, in Section 5 we summarize our main conclusions.

2 LITERATURE REVIEW

The dominant view on simulation use, as described in many course books and implemented in software, is still in conformity with the "hard" OR paradigm of optimizing systems of operations (Robinson 2001). In this view, the analyst has a major role in the design of models and solutions, building on representative data on system design and behavior. The "hard" view on simulation use pays little attention to the separate role of visual simulation models in facilitating active user participation, for creating better and accepted solutions. Moreover, uses of simulation other than analysis, which primarily rely on visual interaction, are easily overlooked. Examples include simulation being used as a technique for knowledge elicitation (Robinson et al. 2005), or as a means for staff training or student education in operations management, see, for example, Chwif and Barretto (2003). In fact simulation literature provides rather scarce answer to such opportunities.

Let us now shortly consider the notion and meaning of a modeling framework. *Modeling frameworks* specify a procedure for detailing a model in terms of its elements, their attributes and their relationships. Examples include the general case of systems representation and domain related cases. The general case anticipates conceptualization building on elementary system elements, i.e., components, including their variables and parameters, and mutual relationships, see, for example Shannon (1975). Domain related cases refer primarily to the military field, see for example Nance (1994). Outside this domain, examples are scarce (Robinson 2007a).

We consider our work on the development and use of a modeling framework as a means for exploiting opportunities on participative engineering. Essentially, a modeling framework should offer the analyst explicit guidance in creating domain specific conceptual models for simulation, which appeal to model users – allowing them to participate in solution engineering. So far we related the use of the modeling framework to model coding in a rather straightforward way (Van der Zee and Van der Vorst 2005), by typifying elementary object classes and their relationships for manufacturing systems. Its potential, use and role for conceptual modeling, and solution engineering are addressed in this article.

3 MODELING FRAMEWORK

In this section we discuss our modeling framework for manufacturing simulation in rough detail. First we consider its core, a reference architecture for manufacturing systems. Next, we show how it may be employed for conceptual modeling. Finally we relate its use to simulation methodology. More details on the modeling framework and its underpinnings can be found in Van der Zee and Van der Vorst (2005), and Van der Zee (2007).

3.1 Reference Architecture

To represent entities in the manufacturing domain we define three main classes in our modeling framework: *agents*, *flow items* and *jobs* (Figure 1, cf. Booch (1994). *Agents* represent the infrastructural, *non-movable*, elements of a manufacturing system such as workstations, information systems and managers.

Flow items constitute the *movable* objects within manufacturing systems. We include four types of flow items in the modeling framework: *goods* (like, for example, materials, parts, semi-finished products), *resources* (like, for example, manpower, tools, vehicles), *data* (like, for example, feed back on control decisions, forecasts) and *job definitions*. Goods, resources or data seldom flow spontaneously from one location to another, as mostly some form of control is exercised over agent activities. Typically, the activities of agents are directed by messages. We address this type of messages as *job definitions*.

In a manufacturing system agents and flows are linked by jobs, i.e., business activities. In our job oriented worldview we assume that each business activity relates to a job, being the responsibility of a specific agent. In line with practice it is possible to define more specific classes of internal agents, where the type of flow item serves as a parameter. For example, a workstation may be considered an internal agent of a processor type handling goods. In a similar way control systems and decision-makers may be defined as internal agents producing job definitions.

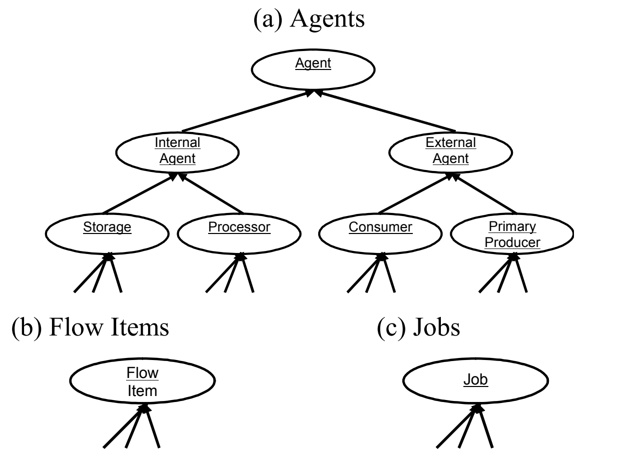

Figure 1: Classes in the Modeling Framework

The definition of a structure for an internal agent is shown in Figure 2. It was inspired by the atomic model as defined by Zeigler (1990). The state of an agent relates to its attributes and their values. Attributes concern buffers and transformer. Buffers model the temporary storage of those flow items which are the prime subject of a future job or which have a facilitative role in job execution (resources, information). The transformer reflects a set of jobs in execution, and contains the flow items that are related to these jobs.

The handling of incoming flow items is dealt with by input operations. An input operation puts flow items in the right buffers. In a similar way, the output operations take care of sending the flow items resulting from a job to other agents. The initiation of a job is enabled by rules comprised in the local intelligence. Before a job may be started, two requirements (preconditions) have to be fulfilled: (1) the availability of a job definition, and (2) the availability of the required input for a job.

Agents communicate with other agents by exchanging flow items, being the net result of job execution. They are denoted as associations, i.e., lines crossing the oval, see Figure 2. Two specializations of the basic type of relationship concern: (1) The relationship between an internal agent and its controller (Figure 3), and (2) Relationships between external and internal agents. Control is assumed to be effectuated by the sending of job definitions from a controller object to an internal agent, denoted as Int. Reversely, a subordinate can send information (F(I|D)) on its status to its controller. For external agents we distinguish between customers and suppliers.

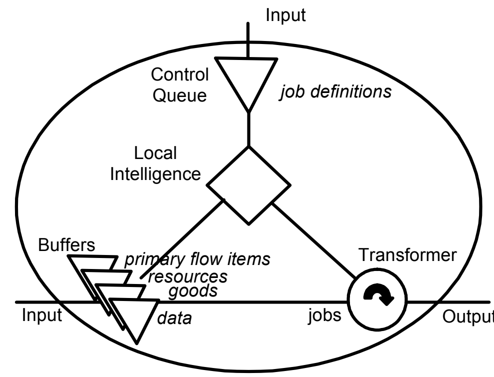

Figure 2: Structure for an Internal Agent

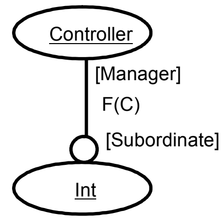

Figure 3: Control

In line with our job-oriented view we assume the execution of jobs by agents as the driving force of business dynamics. Job execution is related to a procedural three-phase description (Pidd 1998).

3.2 A Method for application

Figure 4 displays the elementary steps making up a method for application of the modeling framework. Basically, three steps are foreseen. The first step foresees the determination of a system boundary, clarifying which entities are to be included in the study. The second step foresees the definition of entities following a top-down refinement process, according to which sub models may be decomposed into components up to some basic level. Outcome of this step should be a hierarchical “skeleton” model, which defines (non-decomposable) elements and the way they are organized in terms of (decomposable) sub models. In our modeling framework elements correspond to agents, flow items and jobs. Sub models are related to compound agents, flow items and jobs. For example a compound agent may be used to represent a planning system, which may be further decomposed into a planning hierarchy of agents. In turn, such a compound agent may be associated with compound jobs (to be further detailed and distributed among the respective agents), and compound flow items (to be further decomposed in terms of materials and data). Two elementary questions in model decomposition concern the choice of a basic level, and sequencing of the decomposition activities.

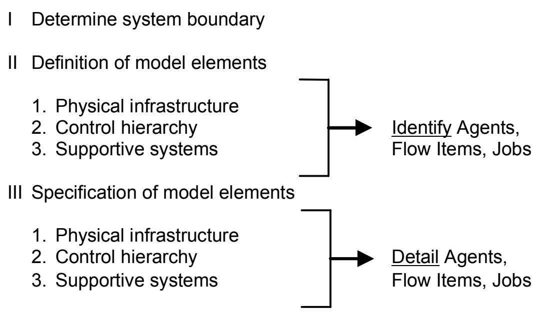

Figure 4: Modeling Framework – Method for Use

In step 3 the skeleton model is being detailed "bottom up". Bottom up construction boils down to a specification of agents, flow items, and jobs, according to the format set by the modeling framework.

3.3 Use in conceptual modeling

To relate the use of our modeling framework to methodology for conceptual modeling, we start from the definition of Robinson (2007b), which is built on a recent and thorough literature review. In his view conceptual modeling consists of five sequential, but iterative, key activities:

- Understanding the problem situation.
- Determining the modeling and general project objectives.
- Identifying the model outputs.
- Identify the model inputs.
- Determining the model contents (scope and level of detail).

Direct contribution of the modeling framework is meant to be in the specification of model contents, being the starting point for model coding. However, we feel that important, indirect benefits of the framework arise from a clear and insightful definition and specification of model elements. Typically, it is meant to support a joint understanding of the problem situation, and – starting from that – a joint creative process in which modeling objectives, inputs (engineering solutions), contents and outputs are determined. In sum, potential gains of the modeling framework for conceptual modeling are assumed to lie in the quality of the conceptual model in a narrow sense – being the precursor to next phases in the study (for example, validity, credibility, utility, feasibility), the quality of the process (facilitation of the analyst and stakeholders in their joint execution of activities), and the quality of outcomes in terms of high performance solutions.

4 CASE STUDY

To illustrate and evaluate the use of the modeling framework for conceptual modeling, and engineering support, we consider the aforementioned simulation study on the redesign of the planning and control system for the production of 'liquids' (fluent coffee extract) in a coffee manufacturing plant. First we consider the case background, and supply a system description. Next, we consider project organization, and give an overview of the outcomes for the conceptual modeling activity. Finally, we determine, and evaluate the contributions made by the modeling framework to the simulation study, and for engineering support.

4.1 Background

At the start of the project the management acknowledged the need for a rigorous redesign of the current planning system. This was triggered by the outcomes of the preceding and ongoing "lean" projects on the production system's design. They resulted in significant changes and improvements to the organization of the operators, their working procedures and the machinery. In addition, observations on the current planning system revealed several shortcomings:

- Performance: High inventory costs due to excessive stocks for specific products. Low service level for other products (out of stock). Further, customer delivery times are considered long.
- Planning logic: Planners and operators experience a high level of system nervousness, caused by ongoing rescheduling and replanning activities to respond to changes in the production environment
- Staff organization: The planning system tends to be labor-intensive, involving many people and much effort in tuning their activities.
- Model of the production system: General feeling of inefficient use of production facilities, due to incomplete/distributed knowledge of the system.
- Supportive systems: Next to the ERP system the company maintains a poorly organized set of databases and spreadsheet applications.

An important outcome of the lean projects with respect to the underlying production system concerns the decision to produce liquids using dedicated resources only. This facilitates a more efficient and effective planning logic, in which the production of liquids is decoupled from their packaging. This logic builds on the notion that production processes before the (customer order) decouple point relate to just a few types of products (blends) for which demand is rather stable over time. However, the packaging of liquids is rather customer specific, resulting in many SKUs.

The project focus was on improving system performance (costs, service level) by: correcting and adapting the model of the production system, working out the new planning logic in detail, and studying consequences for staff organization and supportive systems. In an early stage of the project the choice was made to adopt simulation as a supportive tool for the project. The choice was motivated by: (1) the flexibility of simulation in modeling system complexity in terms of the number of production stages, and the variability and uncertainty associated with each of them in terms of, for example, product yield, and down times, (2) the wish to reduce project risk by studying and testing planning logic in a dynamic setting before its actual implementation, and – last but not least – (3) the need to have a common and insightful model to reflect on, as the engineering of the planning system is a team effort, relying on the distributed skills and domain knowledge of management, planners, and process engineers.

4.2 System description

The first step for producing liquids concerns the roasting of alternative types of green coffee beans (Figure 5). In a next step so-called "coffee blends" are extracted from these beans. Here each blend is related to a certain mix of roasted coffee beans. The liquid blends (liquids) are further concentrated in a number of steps to make them fit for use in coffee machines. In a next production stage the blends are packaged. Production steps are decoupled by buffer tanks. Product quality considerations set restrictions to the length of stay in a buffer. Product changeovers are related to sequence dependent product losses. Also product yields may be dependent on quality of the green beans, and process parameters.

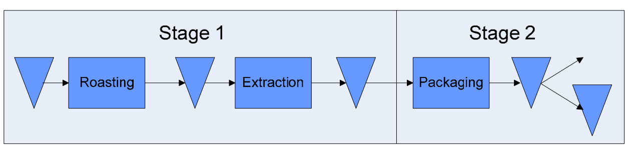

Figure 5: Production process

4.3 Project Organization

In this project conceptual modeling was not just about abstracting a model from a real or proposed system (Nance 1994), but about developing a new planning system as well. The system development was assumed to result from a co-creative team effort, see above, in order to guarantee adequate, good, and credible solutions. Team set up was therefore considered vital. The team was composed of:

- Head of planning and logistics department: Responsible for implementing the planning system.
- Head of supply network planning: Main user of the new planning system.
- Change agent of the Lean Team: Facilitator in applying proposed changes, and domain expert on the production process and lean manufacturing.
- Two external researchers/experts on logistics and simulation modeling.
- Junior researcher: Project manager and developer of the conceptual and coded models.

This kernel team met on a regular basis - once every two/three weeks. Essentially, meetings were considered elementary stepping stones in an incremental approach towards planning system engineering and modeling. Typically, (intensive) discussions centered on specific elements of the planning system, starting from its visualization/demonstration in terms of a conceptual and/or coded model. In order to gain further domain knowledge and answer to the interests of stakeholders, who were not members of the kernel team, a sub-team was formed. This sub-team consisted of several employees belonging to different departments (for example, process technology, R&D, maintenance) and was led by the project manager.

4.4 Overview of conceptual model

In our discussion on the use of the modeling framework for conceptual modeling we will distinguish between its support in specifying model contents (cf. activity 5, in Table 1), and for executing other activities in conceptual modeling (cf. activities 1-4, in Table 1).

4.5 Conceptual modelling

To specify relevant *scope and detail* of the manufacturing processes, and their planning and control (cf. activity 5, in Table 1), we used three formats:

1. A graphical overview of agents, jobs and flow items being exchanged, see Figures 6, 7.
2. Listings of definitions for agents, jobs, and flow items, and their respective detail (text).
3. Flow charts for a procedural description of jobs.

Together, the three formats supplied a complete picture for model coding. Remark, that the listings, cf. (2.), also mention the reasons for including an entity, and its attributes. Considering such information in a default way helps in (1) efficient model building, as it may point at opportunities for model simplification, and (2) may facilitate model re-use or (3) support iterations in the study. Figure 6 shows the new set up of the planning system, in terms of agents, their respective jobs, and their interaction in terms of flow items. It foresees in a control hierarchy, for specifying production orders for the extraction and roasting processes. This is implemented in terms of three agents being responsible for production planning, production scheduling, and production control. Other processes are controlled by local rules. Figure 7 shows the internal structure of an agent.

For this project main contributions of the modelling framework – other than for specifying model contents – were related to the definition of the *experimental frame*, i.e., model inputs, and outputs (cf. activities 1-4, Table 1).

Table 1: Summary of outcomes for conceptual modeling of planning system

Activity	Main results
1. Understanding the problem situation	• Clients: Two groups of clients with an alternative focus on the problem: - Planning and logistics department, aiming at: reducing labor-intensity, increasing transparency of planning activities, reducing nervousness, and lower stock levels, based on better insights in the production system and improved supportive systems. - Lean team, aiming at: lowering order variety on the production floor, reducing buffer usage, a better exploitation of product/process characteristics in planning. • Further investigation revealed: - Many shortcomings in the current planning system, see 4.1. - Promising directions for developing planning logic. For the first production stage (up to packaging) the concept of cyclical planning has been studied, and embraced as an avenue for further engineering. According to the concept blends are produced according to a fixed cyclical pattern. Further engineering concerns cycle contents, cycle length, blend sequencing, the scheduling of spare capacity to deal with demand fluctuations etc. For the second stage, mainly packaging, a customer responsive planning system is foreseen. - Simulation use should be focused on developing the concept of cyclical planning.
2. Determining modeling objectives	• Overall aims: The company strives to become lean. This includes a lean planning system. • General modeling objectives: The model should allow for co-creation of a new planning system. • Specific modeling objectives: reduce (1) stock by at least 20%, without harming service level, (2) variability of waiting times in buffers, (3) reduce nervousness, (4) reduce product waste. • Expectations (process): - The simulation study facilitates a joint structural approach in planning system development. - Adequate solutions build on active participation of stakeholders in planning system development. • Expectations (outcomes): - A planning concept, which is tested off-line in a dynamic setting for its logic (completeness, feasibility). - Analysis of specific scenario's–related to the setup of the planning concept, and estimated customer demand.
2. Determining general project objectives	• Project duration: 6 months for developing an initial planning concept; 3 months for further refinement. • Flexibility: Model should allow for easy adaptations – being built on a robust and jointly understood "skeleton" model, which clearly identifies generic elements of the planning system. • Run speed: Less important for testing logic of the modeling concept. For logistic analysis it is important. • Visual display: Very important. Insightful display of models should support further, joint refinement of the planning system, and solution acceptance. • Model reuse: Model reuse for alternative product groups is considered.
3. Identifying the model outputs	• Performance: (1) Stock reduction: average and spread of stock levels per blend, (2) Service level: average number of stock outs per blend per week, (3) Product quality: average and spread of waiting times per blend for each buffer, (4) Nervousness of the system: Use of reserve capacity (next to fixed planning cycle), (5) Waste: Change over losses. • Cause and effect: several measures.
4. Identifying the model inputs	• Planning system: alternative configurations, for example, choice of cycle length, cycle contents, settings for reserve capacity, local rules for operational control of production processes etc. • Scenario analysis: Alternative demand levels per blend.
5. Determining the model scope and detail	• Model boundary: Main focus is on extraction processes. The roasting process is included to enhance recognition and packaging will be used as an experimental factor. • Model components and their detail: see Sections 4.4, 4.5.
5. Assumptions & simplifications	• Assumptions/simplifications: Not modeled are seasonal breaks, newly developed blends, maintenance stops etc. • Rapid modeling: The logic of the roasting process is not modeled in detail as a decoupling is foreseen between roasting beans and extraction processes.

The problem situation was rather well understood, partly as a result of earlier projects (Van der Hoek 2003; Van Wieren 2006). Also modelling objectives were quite clear. Model outputs concern both measurements related to pre set logistic performance criterions, and their "explanation" in terms of causes (specific configuration of one or multiple system elements) and their effects on performance measurements. Typically, the latter measurements give an insight in the build up of costs (investment, and operational costs), and the composition of time related service measures. Our modelling framework meant significant support for identifying such measurements, as it allows for a graphical overview of all relevant flows, resources involved, and their value adding activities. Remark, that we found that identification of relevant measurements may be further strengthened by a dynamic display of the model. This may be a simplified model based on a MS PowerPointTM presentation, or an initial coded model.

4.6 Evaluation of project outcomes

Robinson (2007b) considers 4 requirements to judge on the *quality of the conceptual model for later phases in the simulation study*. Here we will relate use of the modeling framework for the case to these requirements:

- Validity refers to "a perception, on behalf of the modeler, that the conceptual model can be developed into a computer model that is sufficiently accurate for the purpose at hand". We found that validity of the case model is supported by the natural, explicit and complete notion of system elements, in particular control elements. Here "natural", is the net effect of the modeling framework's conformance to the object oriented standard, and its generic choice of model elements.

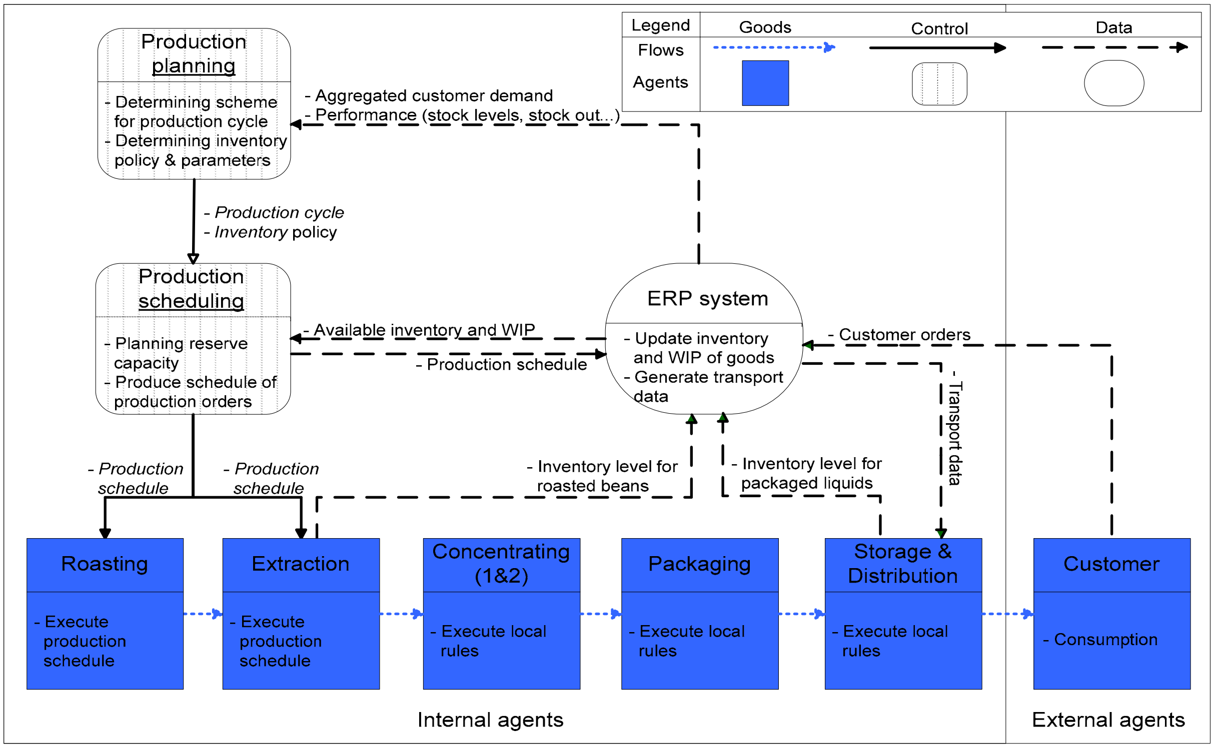

Figure 6: Overview of proposed planning system

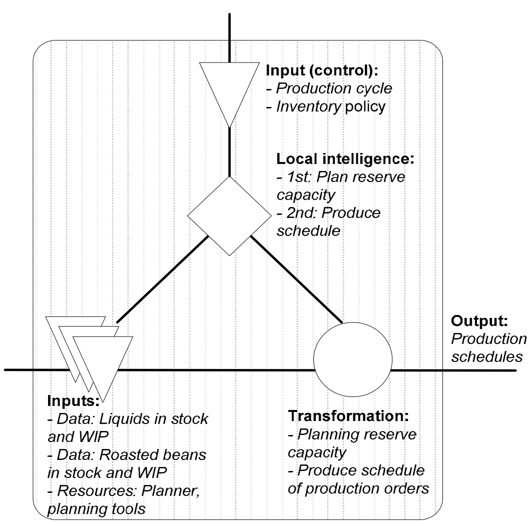

Figure 7: Agent Definition - Production scheduling

- Credibility is defined as "a perception, on behalf of the clients, that the conceptual model can be developed into a computer model that is sufficiently accurate for the purpose at hand". In line with the idea of participative simulation, the distinction between validity and credibility should ideally be removed, or less sharp. For the case study, both modelers and other project team members agreed on the accuracy of the model for subsequent phases in the study.
- The utility of the conceptual model is "a perception, on behalf of the modeler and the clients, that the conceptual model can be developed into a computer model that is useful as an aid to decision-making within the specified context". The modeling framework's conformance to the object oriented standard, and its generic choice of model concepts, support model flexibility, visual display and component reuse. This has been "proven" for the case already in the discussions on planning system set up, being part of the conceptual modeling phase.
- Feasibility, is "a perception, on behalf of the modeler and the clients, that the conceptual model can be developed into a computer model with the time, resource and data available". The modeling framework does offer no direct support on feasibility. Although, the framework allows for straightforward mappings of a conceptual model on a coded model, it does not a priori set restrictions to the use of time, resources, and data.

We relate the *quality of the process* to the degree that stakeholders are involved and participated in model development and solution finding, and its efficiency and responsiveness. Here we saw that the framework offers important help in modeling and engineering, see 4.5. Efficiency and responsiveness benefit from the well-defined and modular set of model elements. Fewer efforts have to be put in a developing and adapting appealing and understandable model elements.

An interesting issue not covered by the method for modeling framework are some further guidelines in model set up:

- Consider whether the organization or supportive system sets "rules". For example, we found that the organization and the ERP system prefer to work according to a weekly rhythm. So a planning cycle should be in accordance with that.
- Be aware of users' possible misperception of simulation being an "all-inclusive" engineering tool. Many engineering issues choices may be solved more efficient/effective analytically.
- Be aware of the fact that conceptual models may both act as vehicles for denoting engineering designs, and for simulation modeling. In most cases there is no need to test the full engineering details by simulation, i.e., through coded models.

The *output of the conceptual modeling phase* concerned a design for the planning system, which was sufficiently valid/credible for implementation. Moreover, the planning system was developed on time for scheduled implementation. Pruned coded models were only used to test logic of the conceptual model for correctness and completeness. In the next phase of the project – not reported here – a coded simulation model was used to fine tune the proposed planning system.

4.7 Engineering support

The development of a new planning system for a complex production system concerns a highly iterative and incremental process. Typically, this involves many (partial) solutions, which may be tested in an analytic way and/or by simulation for their correctness, and completeness, and their impact on system performance. In this case study we used our modeling framework for defining conceptual models, which served both as a basis for analytic and simulation approaches in evaluating solutions.

Let us now consider the meaning of the modeling framework for creating conceptual models that meet the demands for participative engineering, see Section 1:

- Joint overview among project team members: Use of the modeling framework foresees in a graphical, and textual visualization of alternative planning system designs, see 4.4, 4.5, and Figure 6. A display of model dynamics may also be facilitated. However, this requires model coding.
- Identification and visualization of key decision variables: The modeling framework forces an explicit notion of all elements of a planning system, i.e., a planning hierarchy of one or multiple planning systems/planners (agents), their logic (decision jobs), their respective inputs (data, feedback), and outputs (job definitions), and their dynamics (job execution).
- Efficient and well-understood language: The modeling framework builds on just three basic concepts: agents, jobs, and flows. Control is embedded in a natural way by agents representing decision makers, and job definitions being the outcome of decision jobs. Here job definitions model the information required for steering and coordinating activities of subordinate agents in terms of the exchange of flow items.
- Incremental engineering: The method associated with the modeling framework foresees in an incremental model development, see Section 3.2. Iteration in model development and the distribution of development tasks are facilitated by the generic definitions of model elements (see key decision variables), and their modularity, following from their conformance to the object oriented standard.
- Linking planning system and organization: Agents may be used to represent planners and/or planning departments, being interlinked through control and feedback relationships, and each being responsible for their own set of decision jobs.

5 CONCLUSIONS AND FUTURE RESEARCH

In this article we discussed the way simulation may be used as a supportive tool for participative planning system engineering. More in particular, we consider the way a previously developed modeling framework may support the analyst in creating domain specific conceptual models, which appeal to project stakeholders – allowing them to participate in solution engineering. Here conceptual models should serve a vehicle for denoting planning system specifications, a means for mutual communication and discussion among stakeholders, and a platform for further analysis – allowing for simulation and analytic approaches.

We illustrate, and evaluate the modeling framework in a case study on the redesign of a planning system for a coffee manufacturer. We show how model contents may be specified for further analysis, including simulation, in an adequate, i.e. facilitating a direct mapping to model code, and credible way. Further, we make clear how the framework supports system engineering and modeling by clear and insightful system overviews, which explicitly address all key decision variables – here elements of the planning system. Incremental (re)engineering of the planning system is facilitated by the method for the framework. Also, the agent concept, as embedded in the modeling framework, helps in linking planning system and organization. For the case we found the model logic of assistance in defining experimental factors, and model outputs. Finally, the conceptual modeling was successful by producing a system design, which was already valid/credible for implementation.

An interesting direction for future research is the detailing of the method for the modeling framework, by including further guidelines on modeling, building on industrial engineering insights. Further, linking the modeling framework with simulation modeling methodologies, like DEVS (Zeigler 1990) or Petri Nets, may support models that are not only sound from a conceptual point of view, but also have a strong mathematical backing.

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