Design and Engineering of Dynamic Business Models for Industrial Product-Service Systems

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Abstract
In contrast to current product-oriented solutions, Industrial Product-Service Systems (IPS²) involve the integrated development of products and services, thereby guaranteeing high customer value. As a consequence, an IPS² business model characteristically delivers value in a long-term customer relationship. To date, comprehensive research on the design and engineering of dynamic IPS² business models has not been conducted, which has resulted in a lack of modeling and simulation methods that depict their dynamic behavior over the entire IPS² life cycle. In order to fill this research gap, this paper focuses on an integrated business model design and engineering approach with System Dynamics.

Keywords:
Business Model, Industrial Product-Service System, System Dynamics

1 INTRODUCTION

To withstand the increasing competitive pressure in the global environment manufacturing companies are increasingly adopting 'servitization' - a business model innovation whereby existing product-oriented solutions are extended through the provision of related services [1]. Only a few industrial solution providers go one step further and try to react with integrated product-service offerings by means of Industrial Product-Service Systems (IPS²) [2]. On the one hand, this integrated consideration of products and services is a key to competitive advantages, improved interaction between customer and provider as well as a higher profitability within the business relationship [3]. On the other hand, IPS² add complexity to the delivery phase due to the long-term relationship with the customer [2].

In practice, most of these transitions lead to increased service offerings and higher costs, but not to correspondingly higher returns [5]. Empirical investigations have shown that only 21% of manufacturing companies are successful with these service-oriented strategies, i.e. that the majority of servitized firms achieve lower profit margins than pure product manufacturers, especially in the case of large firms [6]. Consequently, dynamic business models that take into account the special characteristics of IPS² have to be developed in order to positively affect firm value by transitioning to an integrated product-service solution provider. This requires methods to enhance learning and understanding of the underlying dynamic business to enable managers to appropriately select, design and engineer a viable business model. The fulfillment of customer value over the entire life cycle is a central aspect of IPS². Dealing with uncertainty, in terms of high complexity, dynamism and a strong complexity, is therefore one of the key challenges for a more detailed analysis of IPS²-specific business models. In this context, it is e.g. important to know who owns which physical part of the product, whose personnel executes which tasks, or who bears what risk.

To date, there has been no comprehensive research done regarding the design and engineering of business models [7]. Furthermore, modeling and simulation methods that depict the dynamic behavior of an IPS² business model over the entire lifecycle are still missing. In order to fill this research gap, qualitative and quantitative modeling methods for dynamic IPS² business models have to be conceptually developed and extended. As an initial step, this article aims at delivering a design and engineering approach for dynamic IPS² business models by means of System Dynamics (SD). SD is a method devoted to the study of the dynamic behavior of systems utilizing a visual modeling and simulation technique [8] [9] [10].

Additionally, a practice-oriented case study of a solution provider's business model is introduced with focus on fundamental modeling structures and their dynamic correlations. Moreover, different simulation runs of selected business scenarios are accomplished to support the management's decision process in finding an adequate strategy for the sustainable implementation of an innovative business model. This case study serves two major objectives. The first is to describe the introduced approach by using SD in a practical perspective. The second is to demonstrate how SD can be used as a realistic and capable method for business model design and engineering.

2 DIFFERENTIATION OF IPS² BUSINESS MODELS

The heterogeneous understanding of the business model concept results in a relatively unstructured discussion in the engineering and economic literature [7] [11]. The first requirement for the exploration of business models for IPS² should be a definition of what is meant by a business model. An IPS² is a solution for a customer and is tailored to an individual situation. Thus, in the majority of cases, an IPS² is unique. A business model varies according to the dynamics of an IPS², e.g. as caused by a change of the customer's requirement and hence, the underlying product-service combination. Business models for IPS² are distinguished by the fact that they characterize the specific relationship between a provider and a customer, while other value-adding partners can also be involved (e.g. suppliers) for the provision of an

IPS² [12]. Thus, a business model for IPS² is defined as follows:

The business model characterizes the relationship between a provider and a customer as well as potential third value-adding parties over the entire life cycle of an IPS². It describes the value proposition, the risk distribution, revenues streams, and the property rights for all parties in the IPS² network as well as its organizational implementation.

The business model is not equivalent to the strategy of a company. The strategy describes long-term objectives of an enterprise and the resulting behaviors to achieve these objectives [13]. A strategy can be implemented through multiple business models, because the company may choose a different model in cooperation with each customer. This solution space is defined in the business concept. The business concept describes which business models a company potentially offers, based on its strategy [14] [15]. By contrast, the IPS² business model illustrates the customer-specific configuration of concrete characteristics of the IPS² business concept.

3 BUSINESS DYNAMICS

3.1 Current approaches

To date, dynamic aspects of business models have only been sporadically examined in the technical literature. MEINHARDT investigated the change of business models in dynamic industries. In particular, the motives for the change of business models in response to changing market conditions were examined [16]. GRASL uses SD for modeling the dynamics of business models in the context of professional service firms and simulating its behavior under varying conditions [10]. These existent approaches, that are used to analyze specific business models, differ greatly depending on the focused branch or industry [17]. The majority of research is based on static conceptual frameworks [18] or case-specific analyses [19] [20].

Despite this huge variety of existing studies, there has little fundamental research been done on business models for IPS², especially with focus on their dynamics and flexibility. IPS² are namely characterized by their dynamic adaptability over the entire life cycle corresponding to changing customer needs [21]. In addition, they are defined by an integrated and mutually determined planning, development, provision, and use of products and services including its immanent software components in business-to-business applications and represent a complex knowledge-intensive, socio-technical system [2] [4] [12]. Hence, modeling and simulation methods that depict the dynamic behavior of the corresponding IPS² business models over the entire lifecycle are necessary. The further development of the business model ontology and the corresponding partial model approach for IPS² business models from MEIER and RESE in terms of dynamics and flexibility is therefore one of the key challenges of the business model research in the context of IPS² [7] [11] [22].

3.2 System Dynamics

SD is a method to enhance learning and understanding of complex socio-technical systems, especially in an complex business environment [8], and is thus a suitable tool for analyzing IPS² and their business models. It is based on simple graphical notations to model systems: causal loop diagrams and stock and flow diagrams. There are also other methods for analyzing and simulating dynamic systems, such as discrete event modelling [10] [23] and agent-based modeling [8] [10] [24]. Discrete event modeling is more suitable for simulations at the operational level, SD is more suitable for simulation at high levels of abstraction, agent-based modeling can be used at all levels of abstraction [10] [25]. Due to the interdisciplinary approach of SD [8], it is an adequate simulation method for modeling and simulating IPS² business models, which are positioned at the strategic level. A comprehensive introduction to SD is given by STERMAN who demonstrates how this method is applied especially to business issues [8]. The dynamics of competitive strategy are explored by WARREN [26], the dynamics of strategy and business dynamics in general are explored by MORECROFT [9] and WARREN [27].

SD supports managers of IPS² solution providers in understanding their complex and dynamic business. Just as an airline uses flight simulators to help pilots learn, SD is, to a certain extent, a method for developing computer-based management flight simulators, to help managers learn about the dynamic complexity of their business [8]. Nevertheless, static aspects of the business model cannot be described by means of SD. Hence, an integrated design and engineering approach for IPS² has to be supplemented by further tools, e.g. the IPS² business model morphology [7] [11] [22].

3.3 Team model building with System Dynamics

SD models are often built by teams, that include a facilitator, an expert modeler and policy makers/managers [9] [28]. MORECROFT describes three distinct phases of work that are necessary to build SD models collaboratively [9]. Phase 1 focuses on identifying the problem situation and mapping the relevant feedback structure in a team of five to ten people. In the second phase, the developed stock and flow diagram from phase 1 is converted into friendly algebra. Additionally, a variety of diagnostic simulations are conducted by a subset of the team due to the associated time-consuming nature of this step. In the third phase the SD model is transformed into a specially packaged simulator ('learning laboratory', 'micro world') to communicate the insights with ease, e.g. in workshops [9].

4 INTEGRATED BUSINESS MODEL DESIGN AND ENGINEERING FOR IPS² BUSINESS MODELS

4.1 Requirements on team model building for IPS² business models

A key aspect for successfully developing an IPS² as well as its business model is the combination of various competences and qualifications from the tactic and strategic management level of an IPS² solution provider, e.g. controlling, finance, human resources, ergonomics, etc. In addition, the analysis and integration of customer requirements are essential to develop a sustainable, customer-specific business model for an IPS².

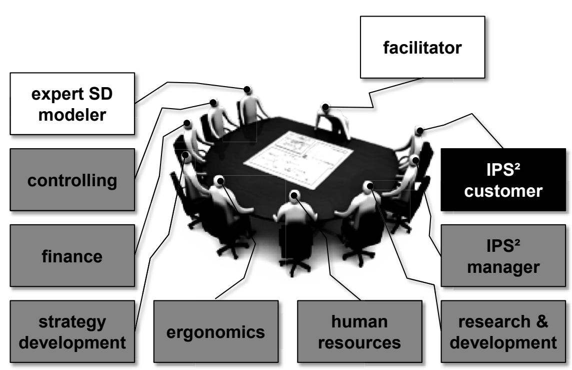

Figure 1: The collaboration of an interdisciplinary management team is essential to design a dynamic IPS² business model (following [9] [32]).

Depending on the problem situation, a selection of relevant policy makers and managers from the provider as well as the customer can be necessary. An exemplary composition of such a team is represented in figure 1.

Accordingly, developing and understanding dynamic business models in such an interdisciplinary management team requires more than technical tools to create mathematical models [8]. An integrated modeling approach for dynamic IPS² business models has to be provided that comprises the following aspects:

- robustness, integrity and completeness of business models,
- generation of a basic (dynamic) understanding of a business model and its attributes (e.g. by visualizing reinforcing and balancing feedback loops),
- decision support through simulation experiments (e.g. to derive a reasonable maintenance strategy),
- benchmarking of business models (e.g. to compare a provider's business model with those of competitors),
- revenue and profit forecasting (e.g. to allow realistic budget planning in controlling and finance).

4.2 Business model design for IPS²

The necessity of a heterogeneous team becomes particularly evident when reconsidering the defined key dimensions of the IPS² business model: value proposition, organization, risk distribution, revenue streams and property rights. Considering these dimensions, the team model building phases from MORECROFT have been adapted to the special needs of dynamic IPS² business models. By analogy, phase 1 'business model design' defines the problem as well as the broad scope and architecture of a dynamic business model in terms of performance through time. ZOTT and AMIT consider business model design from a more static perspective by means of design themes and design content. Design themes refer to the system's dominant value creation drivers and design content examines in greater detail the activities needed to be performed, the linking and sequencing of the activities and who will perform the activities [29]. Business model design for IPS²-specific problems (figure 2, right) includes the qualitative description of a dynamic business relationship.

It refers to defining the business and value logic of this relationship at the strategic level. As an initial step the problem has to be articulated. Subsequently, MORECROFT describes three alternative paths the modeler can take in going from performance over time to a stock flow diagram (causal loop, direct path, sector map) [9]. In addition to this conventional way of SD modeling, IPS²-specific business model configurations can be defined by means of the IPS² business model morphology to receive a blueprint of the business model structure [11] [22]. As a problem-structuring and problem-solving technique, the morphology analysis supports the modeling team in describing multi-dimensional, complex problems qualitatively. Particularly, if such a team comprises persons from various disciplines or with different levels of qualifications, it is essential to provide such a blueprint to give directions during the design process.

4.3 Business model engineering for IPS²

The majority of approaches in the field of business model research are focused on business model design, whereas there is almost no attention for dynamic aspects, flexibility, validation and implementation of business models [30] [31].

Hence, phase 2 'business model engineering' supports quantitative modeling and simulations as a continuous design, validation and implementation cycle (figure 2, left). Subsequent to mapping the problem qualitatively, a variety of diagnostic simulations are conducted (quantitative modeling and simulations). This work is carried out by a dedicated modeling team [9], usually a subset of the original business model design team (figure 1), including the facilitator, the expert modeler and at least one person who has specific knowledge about the value-oriented solution space of the respective customer-specific IPS² business model. To create a robust and well-calibrated simulator, in this phase equations have to be written, parameters to be obtained and graphical functions to be sketched [9].

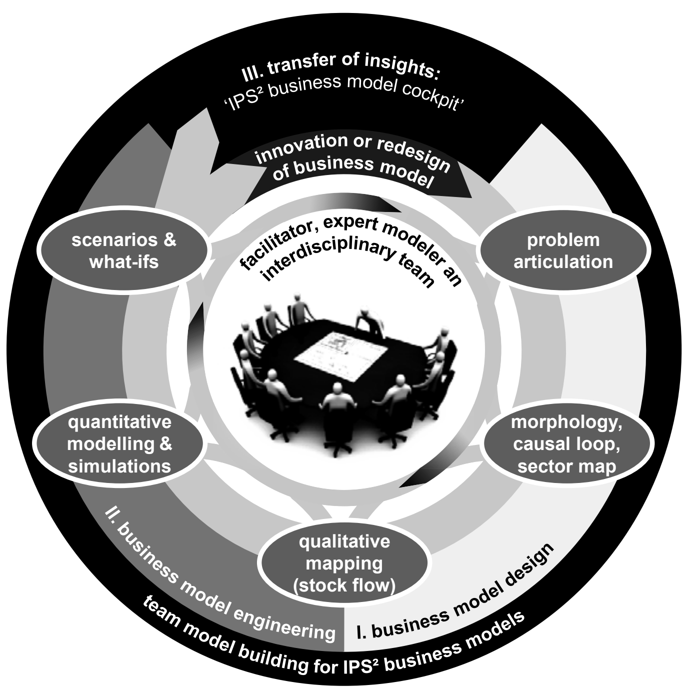

Figure 2: Integrated Business Model Design and Engineering for IPS² Business Models is an iterative learning process.

4.4 Transfer of insights

LAURISCHKAT describes an interdisciplinary team-oriented approach for the IT-supported generation and modeling of services for product-service systems in a business-to-business context. Thereby, a key aspect is the generation of insights and the archiving of know-how of different protagonists for an efficient reuse [32]. By analogy to this approach, in phase 3 'transfer of insights' (figure 2, top) the engineered model is supplemented by an 'IPS² business model cockpit' to easily generate quantitative data for reuse by non-expert model users and to transfer insights to the original modeling team of phase 1.

To give a first insight into the design and engineering of an exemplary IPS² business model with SD, a practice-oriented case study of a solution provider's business model, that focuses on fundamental modeling structures and their dynamic correlations, is now introduced.

5 CASE STUDY

5.1 IPS² solution provider

The respective company is a medium-sized solution provider in the field of tool management and has currently more than twenty service contracts worldwide, especially with automotive manufacturers as well as with its components suppliers.

A guided face-to-face interview with the top management was conducted to gain detailed information about the business concept offered by the company. This guided interview was based on a guideline to structure the conversation, in which the respondent directs the flow of discussion and is enabled to add explanatory details to his response. This first interview has shown that the business concept (see definition in paragraph 2) of the tool management provider is divided into five product-service levels. The first two levels basically concern the trade and readjusting of tools. In the third level a computer based tool-dispensing system is provided, and level four and five comprise an integrated and holistic tool management from developing, producing and procuring tools to prepare them for application in production. Additional services are maintenance, repair, cleaning and readjustment of used tools and defective parts of the machine. In the special case of these provider-driven business models [22], revenue is based on produced units (cost per unit, CPU).

5.2 Business model design

Problem articulation

A second interview was conducted to analyze the requirements of the provider under consideration of the special needs of a specific customer (component supplier for the automotive industry). Following these requirements, the management of the solution provider intended to expand its business concept by a sixth level with availability guarantee of the customer's machines. This innovative level would be characterized by a very intensive cooperation between the customer and the provider.

The most critical issue of this new collaboration-intense business model [22] was the accurate definition of ownership conditions resulting in a high amount of coordination necessities. Furthermore, a revenue model considering the risk distribution had to be developed.

Causal loop diagram and morphology

For complexity reduction the new level was described by means of a causal loop diagram and the IPS² business model morphology [11] [22] with focus on value, risk distribution, and revenue streams. The customer value is based on availability guarantee of the machine by means of tool management services and machine maintenance, even though the machine is in ownership of the customer. This requires an integrated value architecture. Consequently, there are multiple benefits integrated with each other due to a full machine service offered by the provider. Hence, this novel level comprises a holistic tool management from developing, producing and procuring tools to prepare them for application in production while integrating additional machine services, e.g. process consulting, training, maintenance, repair, cleaning and readjustment of used tools. The provider bears the risks for life cycle activities as well as the risks of machine and tool availability. The customer bears the market risks, the risk for the result of the use as well as the risk up until the product sale. The economic value is based on management of activities.

Qualitative mapping

Revenue streams are generated over the IPS² life cycle based on the overall equipment effectiveness (OEE) of the machine. A stock and flow diagram was derived, which includes the value architecture as well as the revenue and cost structure. The overall objective of the provider is to raise the variable 'OEE' of the customer's machine by an integrated tool management in order to achieve a high customer value. Thus, this indicator is also a key variable, which is closely linked to the revenue structure (figure 3, sector frame 'revenue model').

5.3 Business model engineering

Quantitative modeling and simulations

An important issue for quantitative modeling is the structure of revenue generation. For the solution provider this aspect is closely linked to the value and risk model. The revenue is not just a payment for the value generated for the customer, but also a compensation for the risks the provider bears. Therefore, the revenue model is based on OEE which results from the quality, performance and availability rate. A table function was used to represent this relationship based on the provider's experiences with the existent CPU-model.

Scenarios and what-ifs

There are three possibilities to run the model. First, the model can be simulated with data from the past of comparable business cases. Second, a user interface can be used to manually change key variables of the model. Third, a mixture of both strategies is possible. Thus different scenarios can be performed. An exemplary scenario is shown in figure 4. A series of simulation runs is performed to support the management's decision process in finding an adequate strategy for the sustainable implementation of a new business model.

5.4 Transfer of insights

In phase 3 the SD model (figure 3) was transformed into a 'business model cockpit' (figure 4) in order to change key parameters of the business model by input sliders (units, rework). Thus, the above mentioned series of simulation runs can be easily performed by a non-expert modeler.

An important insight for the management was the need of a comprehensive consulting and training plan, which considers the actual competencies and the qualification of the customer's machine operators. In addition, the analysis showed, that it is a challenging task to reliably determine the key performance indicator 'OEE' in practice due to the complex structure of property rights with regard to machines, tools and equipment. Hence, a significant aspect is a reliable monitoring framework of this key performance indicator, which has to be clearly defined and included in the IPS² contract.

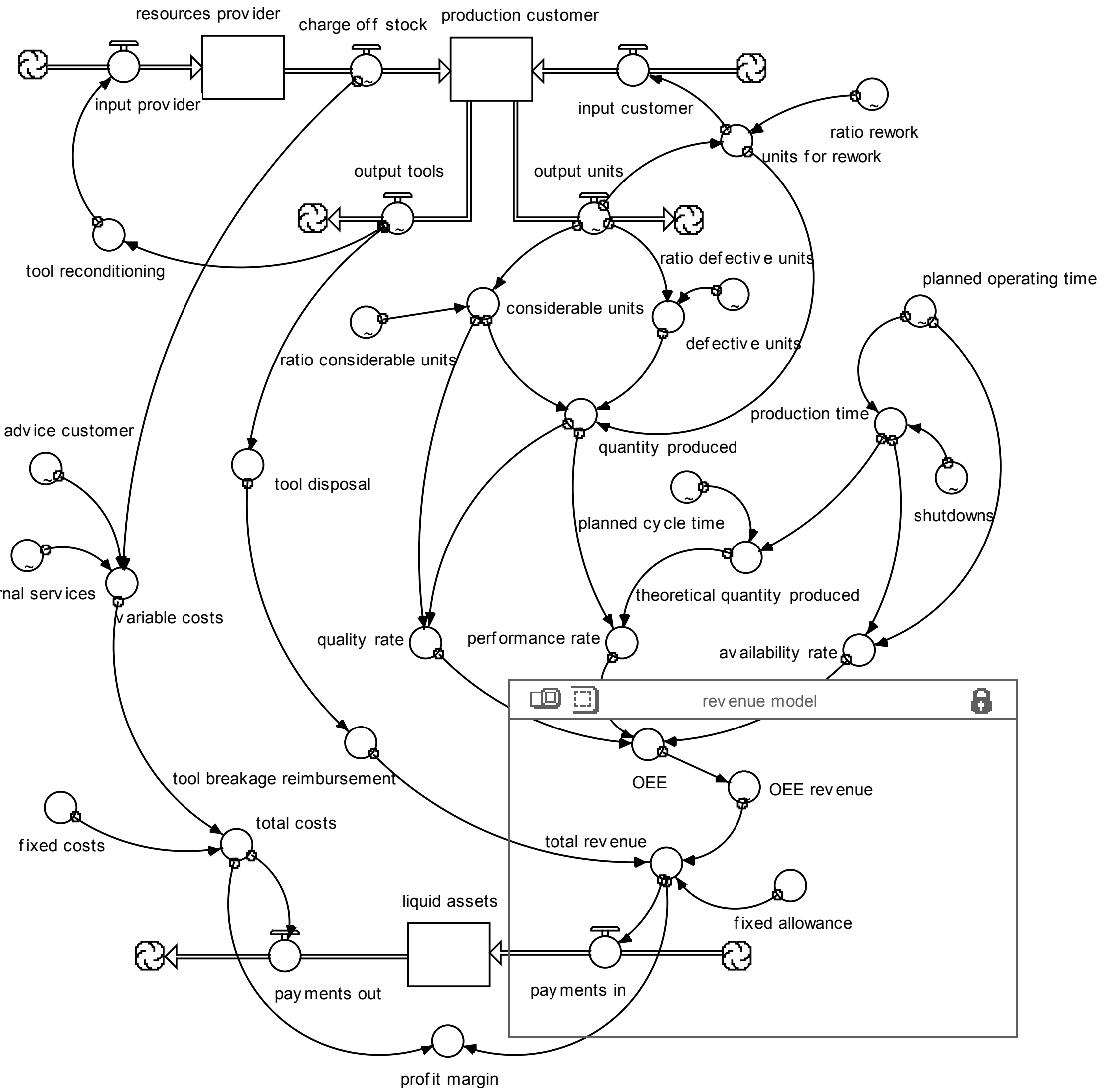

Figure 3: Stock and flow diagram: collaboration-intense IPS² business model.

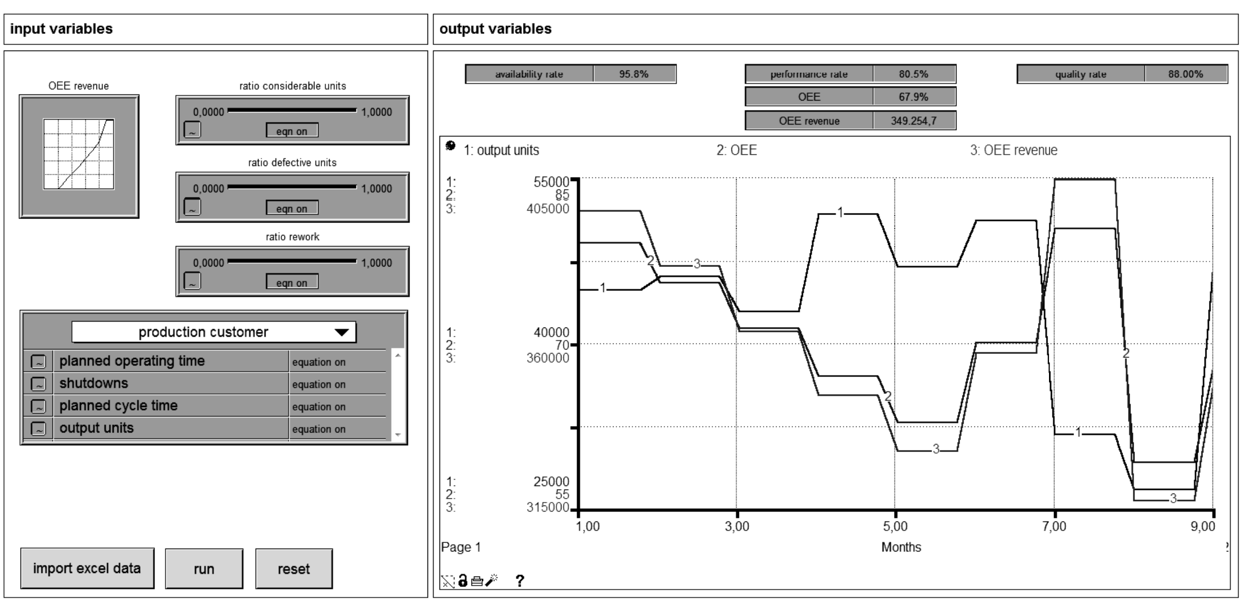

Figure 4: Business model cockpit – collaboration-intense IPS² business model.

6 SUMMARY AND FUTURE PROSPECTS

As a foundation for further case studies and empirical analyses, a design and engineering approach for dynamic IPS² business models by means of SD was introduced. Based on this approach, two in-depth interviews with a solution provider have been conducted to develop an availability-oriented business model for tool management. The conceptual understanding of business models in practice as well as the risk and task distribution between customer and provider were key aspects of these interviews. In addition, it could be identified, that a reliable monitoring procedure for the indicator OEE has to be provided in practice. The described team modeling approach structures and supports the design and engineering process of dynamic IPS² business models. The combination with strategic modeling methods, such as SD, represent an essential contribution for developing new and for adjusting existing IPS² business models. In this paper, SD was used to specify the business model's run-time behavior over time. In addition to the business model morphology, further tools are necessary which specify the business model structure and the mapping of its behavior onto this structure. Considering these aspects, the provision and further development of this approach is extremely important for further investigations.

7 ACKNOWLEDGMENTS

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