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Process chains in cross enterprise production: a module-based design framework

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The emergence of various new concepts in cross enterprise production, which focuses on different market conditions and objectives, has been observed in recent years. Systems supply and consignment storage represent prominent examples. To successfully explore individual potentials of cross enterprise production, the design and implementation of enterprise specific concepts can be supported by the provision of individual process models. Both a multitude of alternative process chain models as well as a suitable methodology for individual process chain design is thereby required. In the following, a module-base design framework for process chains in cross enterprise production using the extended Integrated Production Process Model (eIPPM) is introduced. Based both on the provision of process modules and design rules as the main contribution of the eIPPM as well as a detailed design methodology, the design of individual process chains in cross enterprise production becomes possible. Thereby, the enterprise specific process and task allocation represents one of the major design elements. Finally, two case studies are presented to verify the individual applicability.

Keywords: Process modelling, Design of production systems, Process chain, Cross enterprise production

1. Introduction

Traditionally, cross enterprise production has been considered a single process. However, limitations both in controllability and in transparency as well as an increasing level of process segmentation require abandoning the single unit assumption. As a result, process chain aspects have emerged in recent years. They consider the acceptance of different actors and fields of action as well as an increasingly globalised production and the corresponding need for standardised processes. The necessary overall product lifecycle perspective of a product's process chain (Champy 2002) clearly identifies that the process chain perspective must not be limited to selected processes of the product lifecycle but must consider all relevant processes.

Individual process chain models covering all relevant aspects of cross enterprise production can be useful to improve the enterprise specific process chain knowledge (Puppe 1993, Rosemann 2006) and to explore specific process chain potentials. On the one hand, different process chain objectives lead to different process chain alternatives. On the other hand, a process chain objective can be typically met by different process chain alternatives, though to a different extent.

So far, the domain of process chain modelling for cross enterprise production is rather fragmented. Available modelling concepts both in industry as well as in academia typically stress only selected aspects of process chains in cross enterprise production in terms of scope, modelling content and aspects, design course as well as process variety. The provided concepts (e.g. Bause *et al.* 2002, Krause *et al.* 2004, Lindemann *et al.* 1999, Mehnert and Duerr 2004, Neugebauer *et al.* 2004, Sepet and Warnecke 1998, SCOR 2006, Wheelwright and Clark 1992) usually focus on selected processes in cross enterprise production (e.g. either product and process

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3 engineering, manufacturing or logistics), and only partially consider cross enterprise aspects or are limited to
4 normative aspects (e.g. DIN ISO 9000:2000, VDA 6.1, QS 9000). Additionally, most of these approaches
5 cover only a certain range of process chain variety, as they are rather limited to a selection of predefined
6 process chains instead of providing a step-by-step design methodology.

7
8 The following paper intends to fill the missing gaps as it addresses the module-based design of process chains
9 in cross enterprise production.
10

11 **2. Process chain**

12
13 Foremost, as in industrial production, the term process chain is bound to different definitions. A thorough
14 model-based definition of the addressed process chain concept is given in the following (see figure 1).

15 A “process” can be generally defined as a specific action within a system, where the required transformation
16 results from subsequent changes in the state of dependent system elements (Haberfellner 2002). From the
17 process perspective, a transformation can be denoted as an “operation”. Typical for a process, achieving the
18 element state of a system represents a pre-condition of the subsequent state of change of another system
19 element. Due to this cause-effect relationship, a process consists of at least of two subsequent operations.

20 System elements providing initial states can be referred to as input and system elements with final states as
21 output. Within the process concept, process hierarchies, which are based on process segmentation, can be
22 used. Process composition establishes a superior process called super process and contains one or more sub
23 processes. Decomposition leads to a subordination below the focused process. That is, a process may contain
24 one or more sub processes.
25

26 While the principle of composition primarily refers to the subsumption of processes, whereby the processes
27 are subsequently not distinguishable, process aggregation refers to a subsumption, in which the different
28 processes can still be identified. They are merely considered as one unit and the result can be referred to as a
29 “process chain”. It is defined as a sequence of inter-dependent processes, whereby the output of a process
30 represents a pre-condition, i.e., the input of a subsequent process. That is, the concept of causal system states
31 is extended from a conditional sequence of operations to a conditional sequence of processes.
32 Correspondingly, a process chain consists of at least two subsequent processes.
33

34 Introducing cross enterprises aspects into the system and process perspective, cross enterprise production is
35 performed within a production system, whereby individual subsystems belong to different enterprises. A
36 process chain in cross enterprise production can be seen as a process chain where individual processes are
37 allocated to different enterprises.
38
39

40 **3. Design framework for modular process chains**

41
42 The following chapter introduces an integrated design framework of process chains in cross enterprise
43 production (see figure 2). The proposed framework intends to provide a closed module-based design
44 methodology to systematically design process chain alternatives in cross enterprise production.
45
46
47

48 **3.1 Framework constituents and characteristics**

49
50 Contrary to a mere mapping or representation of an existing area of the real world, the proposed framework
51 supports the conceptual modelling (Davies *et al.* 2004, Schuette and Rotthowe, 1998). Correspondingly, new
52 (“to be”) instead of already existing (“as is”) process chain alternatives for cross enterprise production can be
53 designed. Such approach directly supports an “out-of-the-box-thinking” (Rosemann 2006) to find new ways
54 of conducting process chains in cross enterprise production.
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3 Extending existing approaches, the proposed framework consists of a fully modular process library providing
4 basic design constituents of cross enterprise process chains, a design methodology for specifically selecting,
5 combining, allocating and specifying the process modules as well as a set of pre-defined demonstration
6 scenarios. The demonstration scenarios represent common configurations in cross enterprise production in
7 product and process engineering, production ramp up as well as in production planning and manufacturing.
8 Finally, use cases represent the result of the process chain design activities and constitute individual process
9 chain alternatives for a specific enterprise.

10
11 As the design methodology covers process and process chain design, the underlying production system
12 structures and components are indirectly defined. The reference character of the designed process chain
13 models allows a significant increase to the process chain design efficiency.

14
15 To fully cover all design aspects in cross enterprise production, the proposed design framework starts with a
16 single production system perspective. Contrary to existing approaches, process allocation succeeds process
17 chain design resulting in enterprise specific subsystems. The design framework can be used from both the
18 supplier as well as customer specific design perspective in cross enterprise production.

19
20 Additionally, as the design framework integrates production processes throughout the cross enterprise
21 production process chain, it gives way to overcome traditionally separated process chain design aspects and
22 tasks. As a result, the design methodology is not limited to selected types of cross enterprise production but
23 intends to continuously cover the production processes within a cross enterprise process chain.

24 25 26 **3.2 Framework performance and measures**

27
28 The main objective of the proposed modelling framework is the support of process chain design, particularly
29 in the early design stages. Therefore, the framework aims at the rapid model provision of feasible process
30 chain alternatives for individual customer-supplier relations in cross enterprise production. Based on such
31 models, aiming at fully executable models of process chain alternatives can be a logical next step within the
32 life cycle of such process chain models (Muehlen and Rosemann 2004).

33
34 The modelling success directly depends on whether the modelling framework meets the modelling objectives
35 in cross enterprise production. Correctness, clarity, comparability and efficiency (Becker *et al.* 2000, Schuette
36 and Rotthowe 1998) are well-known high-level statements for effective process modelling (Bandara *et al.*
37 2005), which must be made applicable to cross enterprise modelling.

38
39 In addition to a mere syntactic correctness, semantic correctness postulates that the designed model of a
40 process chain alternative is consistent with the real world, i.e., the modelling framework provides feasible and
41 applicable process chain models. Thus, modelling success is not process success (Rosemann 2006). The proof
42 of modelling success is given in case the proposed process chain models are successfully introduced and they
43 meet the individual process chain objectives.

44
45 The need for clarity and comparability leads to modelling language adequacy. The problem area and the
46 modelling purpose highly determine the necessary semantic powerfulness of a modelling approach. The
47 pursued modelling approach must explicitly consider the underlying current and future modelling objectives
48 (Rosemann 2006). The framework intends not only to provide feasible process chains alternatives for cross
49 enterprise production (“correctness”) but understandable solutions as well. Typically, cross enterprise
50 production is characterized by a high level of involved model designers and users, who must all share the
51 same modelling notion. As a direct result, the modelling language should be rather simple and easy to
52 understand instead of being highly sophisticated. Intuitive access, clearness, cross enterprise familiarity and
53 self-explanation directly increase modelling acceptance.

54
55 Modelling efficiency is an essential constraint to modelling correctness, clarity and comparability. A feasible
56 process chain alternative must be provided within the allocated modelling time and budget (Bandara *et al.*
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2005). The success of modelling efficiency can be proven based on individually agreed and accepted performance measures by the involved model designers and users (Schuette 1999).

4. Process modules

Process chains in cross enterprise production must represent a large and increasing variety of process alternatives. The concept of modularity represents a promising approach for covering this variety (Lindemann *et al.* 1999, Aurich *et al.* 2003). As process chain variety is not only limited to different alternatives, process modularity allows to cope with upcoming changes in process chain structure and configuration.

4.1 Process modularisation

In addition to the well-known modularity of products, the approach can be applied to the related engineering, production planning and manufacturing processes as well. This is already quite common in the domain of product design as well as module oriented segmentation of processes with respect to technical interfaces of products or product modules, respectively (Piller and Waringer 1999). However, corresponding modularized models of process chains in product and process engineering are only rarely available. This is likewise the case for modular process chains in production planning and manufacturing including logistical activities. Hence, an improved understanding of modular process chains and their corresponding design is required. The different processes in cross enterprise production must thereby be modularized in order to ensure general applicability.

Following the well-known alternatives for product modularization (Piller and Waringer 1999), only the concept of free modularization does not require a uniform basis process module (“platform”). Since standardized and individual process modules can be flexibly combined, it can be considered as the only approach that covers the required process variety. Correspondingly, the overall process of cross enterprise production must be segmented into individual processes that perform specific activities (Baldwin and Clark 1997) and are typically allocated to different responsibilities or use different resources etc.

From an external point of view, a process module can be considered as a unit of a process chain, which can be removed, multiplied, reconfigured, and relocated. Due to these properties, process modules can be used as basic building blocks for changeable process chains. To meet the appropriate level of changeability, process chain structures can easily be changed by adding additional process modules or redesigning the existing ones. In contrast to a total redesign, the design can be limited to individual process modules. Finally, process modules can be used on different levels of detail (Aurich *et al.* 2003) and independently of inter or cross enterprise relations.

The flexible combination of process modules depends on the clear definition of process interfaces. Correspondingly, a process module will be characterized as a transformation (change in state) of system elements that are assigned to the system (input) into system elements that are provided by the system (output) (Wagenknecht 2005). The system elements are characterized by a distinctive set of states and deviations of these states. The change in state includes temporal changes. Hence, storing is not merely considered a neutral state of a system’s element but as a time consuming operation that must be carefully taken care of. Additionally, the provided definition supplements the aspect of reuse and changeability. As the state space of a production process, respectively process chain, is defined by the states of the incoming and outgoing system elements, the usability of a process module is traced back to the provided state of change. The well provided and well-defined change in state for certain system elements enables the reuse of process modules. This is valid for the processes in engineering, production planning and manufacturing.

4.2 Extended Integrated Production Process Model (eIPPM)

Following the introduced process chain definition (see figure 1), the extended Integrated Production Process Model (eIPPM) (Aurich *et al.* 2005, Aurich *et al.* 2006, Wagenknecht and Aurich 2005) is used to support the design process (see figure 3). The eIPPM combines the traditional notions of a meta-model and a reference model (Becker *et al.* 2000, Fettke *et al.* 2006) in terms of both model constituents and relationships (meta-model) as well as content (reference model). It extends the general interrelationships as represented in figure 1. The introduction of process modules on different levels of detail and scope covering all relevant development and realization processes in cross enterprise production, *i.e.*, from product engineering to manufacturing, represents a major accomplishment. Additionally, required operations and system elements (resources, information) have been added to the predefined set of available process design elements.

In the extended IPPM, a process is considered as an Input/Output-system, whereby one or more input elements initiate the process implementation. This approach allows the depiction of all relevant system elements to be transformed as well as their states and corresponding changes in state. Correspondingly, a detailed process module can be defined by means of specifying the relevant system elements, their properties and relevant states. To do so, the fundamental principle of object orientation is applicable. Appropriate objects must be identified and specified regarding structures, relations, functions, and attributes.

The overall process chain results from a linkage of single process modules. Fundamentally, as the implementation of a process is considered a sequence of mutual related state conditions, the linkage of process modules to a process chain can be referred to the same conditional principle as well. A defined order between process modules in a process chain is given in case the output of one process module corresponds with the input of another process module. This corresponds to the basic principles of object orientation where the usage of the same class of system elements by different operations clearly defines the process sequence. Therefore, an additional rule of process module sequencing is not required as the sequence related allocation of states is already a part of the process module definition.

Predefined process modules can be considered as an anticipation of the module design process. A broad range of alternative sources for process descriptions in cross enterprise production chains has been used to define process modules. The provided set of more than 180 process modules covering the whole process spectrum of product and process engineering, ramp up, production planning and manufacturing, is based on typically occurring property combinations in cross enterprise production.

The concept of process hierarchies is used to cover the process variety based on the principles of composition and aggregation. The defined process modules and underlying process elements are stored in a module library. The necessary definition of a process module structure relies on the object-oriented principle of object inheritance, while introducing sub classes with additional information, *i.e.*, attributes, to a specific class of process modules in a stepwise manner. The successful selection and allocation of a process module is based on the top-down-decomposition of the design task.

4.3 Software support

To secure sufficient transparency and applicability of the process library approach, a powerful modelling notation and corresponding software for process chain design is indispensable. This combines both the aspect of process as well as object orientation. However, existing software tools face serious limitations for modular process modelling. This refers in particular to the thorough definition of process modules and underlying elements, their reusability and adaptability, the applicability of process hierarchies in process chain design, and the possibility for enterprise independent process chain design to achieve a flexible process allocation. Some of the limitations can be traced back to alternative process notions and varying degrees of user friendliness. As a result, to fully cover the modelling requirements in process chain design, different

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3 modelling notations and corresponding software addressing different aspects in process chain modelling must
4 be combined (Jesko and Endig 2000). For the software based definition and storage of process modules in a
5 module library, the UML-based state-of-the-art CASE-Tool TOGETHER is used. Process modules and
6 elements are defined using class diagrams.
7
8

9 **5. Design methodology**

10
11 The applicability of a design framework strongly depends on the availability of a powerful design
12 methodology. Correspondingly, to achieve the required objectives in cross enterprise production, the proposed
13 framework includes a systematically design procedure in an idealized and generalized manner. The design
14 methodology describes the concept for applying the design constituents (Fettke *et al.* 2006), i.e., eIPPM and
15 the process modules, within the design framework.
16
17

18 **5.1 Aims and characteristics**

19
20 For every design case, a detailed model of a required process chain using the extended IPPM model (see
21 figure 2) can be derived. Due to the usage of process modules, the design methodology is not a simple
22 selection of a process chain alternative taken from a set of predefined alternatives, which are based on the
23 stepwise detailing of requirements. Instead, the design methodology aims at systematically selecting,
24 combining and configuring process models with careful consideration of both customer as well as supplier
25 requirements. That is, the design methodology allows to systematically design reference models for a whole
26 process chain out of predefined process modules. The combination of process modules allows to design a vast
27 variety of individual process chains, which are particularly necessary for cross enterprise production.
28

29 Following the systems engineering approach, the major steps for the design of process chains are defined as
30 the elaboration of the problem (or initial situation), the design objective, and design solution. All the major
31 design steps are linked via hierarchical control loops. As a result, the design steps can be repeated until a
32 design solution is found. To design an appropriate process chain design solution, a design strategy is chosen
33 similar to the “planning” activity as defined within the domain of artificial intelligence (AI) (Puppe 1993).
34 That is, the objective of process chain design consists of finding a closed graph that transforms the input into
35 the required output as identified in the initial situation. Correspondingly, the design task is not a question of
36 selecting a predefined process chain graph.
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40 **5.2 Design activities**

41
42 The major steps of the module-based process chain design methodology will be described in the following
43 (see figure 4). They are based on common heuristics for system design (Suh 1990, Maier and Rehtin 2002,
44 Yoshikawa 1989) made applicable for process design and are already inherent in the extended IPPM model.
45 The design course must rather be understood as an application-dependent design guideline instead of a fixed
46 algorithm that must be strictly followed.
47

48 *Decomposition:* The chosen approach applies the concept of decomposition and corresponding
49 modularization. Following the initial identification of the basic design objective (required change in state), a
50 decomposition of the corresponding transformation can be useful. This leads to a set of additional
51 intermediate states of system elements. As a result, the design task of finding an appropriate path must not
52 only cover the input and output states of system elements, but the intermediate states as well. As with the
53 design of process modules, the applicability of the decomposition principle strongly depends on the
54 availability of domain specific knowledge (Suh 1990) (“design patterns”). Therefore, summarizing a range of
55 existing approaches, a predefined set of decomposition principles is provided covering common structural
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principles for system design (e.g. top-down), product design (e.g. modularization), material flow (e.g. flow structures), planning (e.g. horizon, resources), information processing, and problem solving.

Search: Following the process decomposition, the actual process chain design activities correspond to a search and selection of appropriate process modules. For this, either predefined process modules of the module library or newly defined use case specific process modules can be used. The module selection is based on the required fit of the process module. This successfully matches the state of change provided by a process module with the required state of changes. That is to say, from the design point of view, design starts with the design of required transformations and sub-transformations representing necessary states in change. Subsequently, an appropriate process module must be selected. Fortunately, as relevant states are already defined during the decomposition, the following search of appropriate process modules already leads to a given process structure. An ex post definition of an appropriate order among the process modules is not required.

Allocation: The search for applicable process modules is tightly linked to the enterprise-related allocation of the identified process modules. Process allocation is possible on every level of decomposition (and detail). In addition to the specific market position of an enterprise (e.g. market power), allocation can be based on the sufficient availability of enterprise specific competencies, respectively, knowledge (Mehnert and Duerr 2004, Neugebauer *et al.* 2004). Whether required competencies are available or not, e.g. indicating uncontrolled processes and correspondingly alternatives of process outsourcing, an allocation might be useful. In the rare occasion of alternative enterprises providing the same competencies, the allocation decision is typically solved based on economic terms, *i.e.*, the cheaper provision of a production process.

Specification: Finally, due to the remaining limitations of process modularity, an enterprise specific module specification (“object instantiation”) might be required. The enterprise specific customization (e.g. supplementation, modification) and verification of process characteristics allows to fully cover the broad range of alternative process chains in cross enterprise production.

Finally, process composition can be useful for processes that have been allocated to a supplier or customer and are thus not part of the enterprise specific production system. In such cases, a rather general process description is usually sufficient (Rosemann 2006). The simplification of the process chain model and the reduction of model complexity are the direct results.

The application of the provided set of design activities strongly depends on the specific design task. As the design steps are linked via hierarchical control loops, the steps of process decomposition and search can be particularly repeated until appropriate process modules are identified. Moreover, allocation represents a possible local terminating criterion as process modules that have been assigned to a different enterprise do not have to be further considered. Process specification is only needed in case the enterprise specific process conditions significantly differ from the provided set of process modules. This might be more likely for highly individual small and medium enterprises than for larger enterprises with usually more standardized processes.

The process chain model, upon its successful evaluation (module fit), can be used as an individual master to implement such a process chain.

6. Process chain alternatives

The decision to implement process chains in cross enterprise production can be supported by the availability of design examples and design experience. Therefore, a set of pre-defined process chain alternatives (“demonstration scenarios”) of cross enterprise production is provided, which take care of different requirements and conditions (see figure 5). Pre-defined process chain alternatives combine the traditional notions of a reference model (scope) and use case (application) (Fettke *et al.* 2006).

6.1 Demonstration scenarios

The demonstration scenarios represent different, but common alternatives of cross enterprise production and allow the identification of possible usage of information systems, tools and methods. The defined set of 12 scenarios covers a broad range of process chain alternatives*. The spectrum covers different levels of customer integration into the product and process engineering processes (e.g. part-, module supplier). Different alternatives of cross enterprise integration into the production planning and manufacturing processes (e.g. Just-in-sequence, Kanban) including logistical aspects are likewise covered. The notion of demonstration scenarios extends the conventional concept of predefined process chain models, *i.e.*, not module-based process chain modelling. In case of predefined process chain models, the user must choose an adequate design out of a predefined set. However, due to the high variety of process chain alternatives, this approach is usually limited to a very generic level or only to a limited range of enterprises. In the proposed framework, the demonstration scenarios are results of the design process for selected cases. The shortage of the design process for representative cases is only the minor benefit. It mainly allows the designer to become familiar with the design concept. Every demonstration scenario can be redesigned based on the provided design methodology and using the provided process modules and elements stored in the corresponding libraries. As a result, the design process is not limited to the search through these predefined process chain models but covers a much broader variety of process chain alternatives. The individual reproduction of the design process for the pre-designed demonstration scenarios allows gaining improved experience in process modelling.

6.2 Software support

In addition to the CASE-Tool TOGETHER, which strongly supports the object-oriented definition of the process element and module libraries but offers limited support for process chain modelling, process-oriented modelling software has been additionally used to represent the demonstration scenarios. The process modelling software AENEIS allows a fast and efficient design of alternative process chains. The software particularly considers the required level of user friendliness based on a proprietary process notation, which is however more intuitive. Thus, the process chain modelling is not limited to software experts but can be used by beginners as well.

To secure a closed design process, designed process chain models can be converted into an activity diagram based UML-notation as supported in the CASE-Tool. This means that the coherence between the different modelling notations and software must be manually checked. However, the compromise between user friendliness and intuitive access on the one hand, and modelling powerfulness on the other hand, is only temporarily due to the continuous advances in commercial modelling software.

7. Case studies

As it can be concluded, the modelling framework rather intends to support the modelling process itself instead of providing ready-to-use process chain models. Correspondingly, the applicability of the proposed design framework is illustrated based on two successful design courses. The given case studies from the automotive industry depict the possible variety of initial design objectives and constraints, individual design courses as well as design results. Figure 6 depicts the alternative information flows within the two case studies. The implemented design resources and provided documents are denoted for each individual design process. The common aspect of both design examples is that there has been a limited availability of information to describe the necessary process chains in detail.

* For a comprehensive compilation of the provided process modules and demonstration scenarios see <http://fbk.cck.uni-kl.de/rupp>

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3 The first case study (“case I”) addressed the development of a business concept pertaining to a tool
4 maintenance service provider. Being part of a larger automotive supplier, the department intended to outplace
5 itself as an independent service provider. To do so, they have been looking for appropriate ERP software
6 (ERP - Enterprise Resource Planning) to run such process chains. However, successful and comparable
7 business models have not been available. The second case study (“case II”) has been primarily addressing the
8 reorganization of a cross enterprise production process chain with particular focus on logistical processes.
9 Although there has been some initial knowledge of a possible process chain alternative, a detailed concept of
10 how to integrate the suppliers has been inadequate.

11
12 The design framework has proven to increase the knowledge base for both case studies. During the course of
13 the design methodology, modular process chains have been designed using both the process module library
14 (case I) as well as a predefined demonstration scenario out of the process chain library (case II). In both cases,
15 additional activities and system elements have been added to the process elements library (e.g. for
16 maintenance in case I, for invoicing in case II). The final process chain designs could be published among the
17 process chain participants via a web interface of the AENEIS-Tool using an .html-format. The application of
18 the design framework has led to the successful provision of case study specific documents in both case
19 studies, which detail relevant information for the implementation of the chosen process chain alternative. An
20 organization manual depicted all process chain elements in a listed manner (case I). Checklists covering all
21 relevant internal and external processes within the cross enterprise process chain permitted carefully
22 documented relevant process activities, responsibilities, and tools (case II). The thorough definition of a
23 project schedule for implementation indicated all relevant project activities, resources and due dates (case II).

24
25 The two case studies nicely depict the alternatives of Out- and In-sourcing processes, especially for the context
26 of cross enterprise production. The strategic In-sourcing of the manufacturing resource engineering processes
27 represents a major design result within the cross enterprise production process chain of the tool maintenance
28 service provider (case I). The Out-sourcing of all incoming goods processes (e.g. inspection, storage,
29 charging), following the concept of a supplier managed consignment storage, can be seen as the major
30 modification within the cross enterprise production chain in the second case study.

31
32 For both case studies, the success of the individual design activities has been measured both in terms of
33 feasible process chain alternatives as well on the individual performance of modelling efficiency. To fully
34 evaluate the improved modelling efficiency, the case studies would have required matching the new design
35 framework with former modelling activities. Due to the individuality of the design tasks, the evaluation of
36 modelling efficiency was limited to a mere qualitative comparison to former design activities and the
37 individual impression of the involved model designers and users. The time required to provide feasible
38 process chain solutions has been a major performance indicator in both cases. In the past, modelling activities
39 in the enterprises have been mostly characterized by a time-consuming search for modelling information, *i.e.*,
40 concept experts, the actual modelling and the continuous matching of model designers (“modelling experts”)
41 and model users (“modelling novices”). In both cases, it has been reported that the application of the modular
42 design framework significantly accelerated the process chain design course. Based on the individual
43 perceptions, the required time for the process chain design could be presumably reduced from months to days.

44 45 46 47 48 49 **8. Summary and outlook**

50
51 The design of process chains in cross enterprise production can be significantly supported by systematic
52 design approaches addressing the conceptual modelling of cross enterprise production chains. In this paper, an
53 integrated design framework for modular process chains has been proposed. The process module approach,
54 the pre-definition of a comprehensive process module library, a domain-specific design methodology and a set
55 of pre-defined demonstration scenarios represent major elements of the proposed design framework. The
56 closed design course to cover the broad variety of alternative process chains in cross enterprise production,
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3 | covering product and process engineering, ramp up, production planning and manufacturing, can all be seen
4 as the major benefit.

5 While the concept represents a general and open framework, future research work is required. Additional
6 efforts are required to support process chain design tasks on a more detailed level, e.g. specific aspects of
7 manufacturing processes. Moreover, the proposed design methodology can be seen as a top-down, outside-in
8 approach that is typically suited for the overall redesign of process chains. To cover additional design aspects
9 of process chains, e.g. the substitution of process modules or the introduction of new logistic methods, the
10 design methodology must be extended by a bottom-up, inside-out approach.
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12

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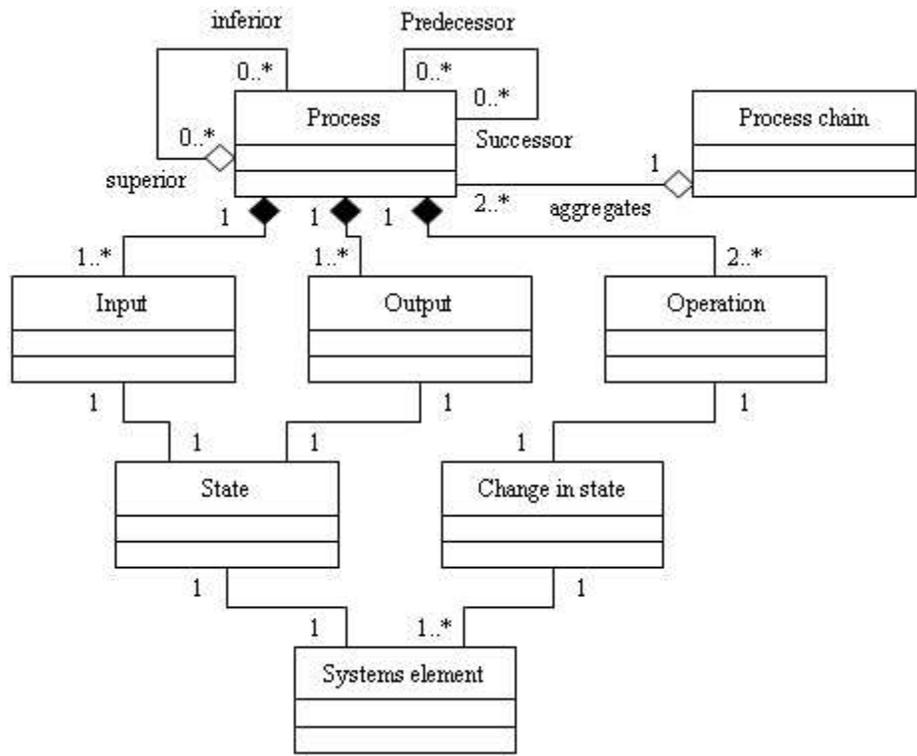


Figure 1: Class diagram of a general process chain
77x63mm (150 x 150 DPI)

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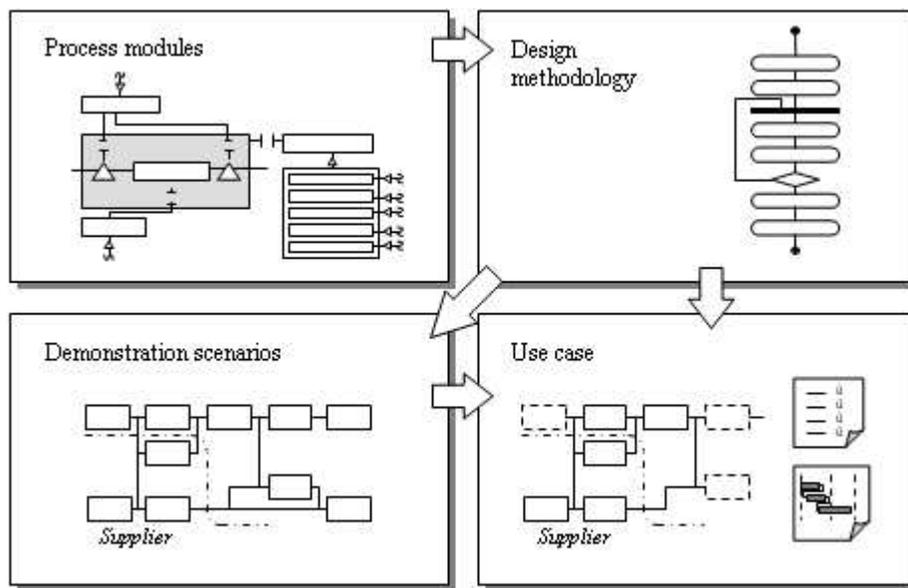


Figure2: Design framework for modular process chains
77x49mm (150 x 150 DPI)

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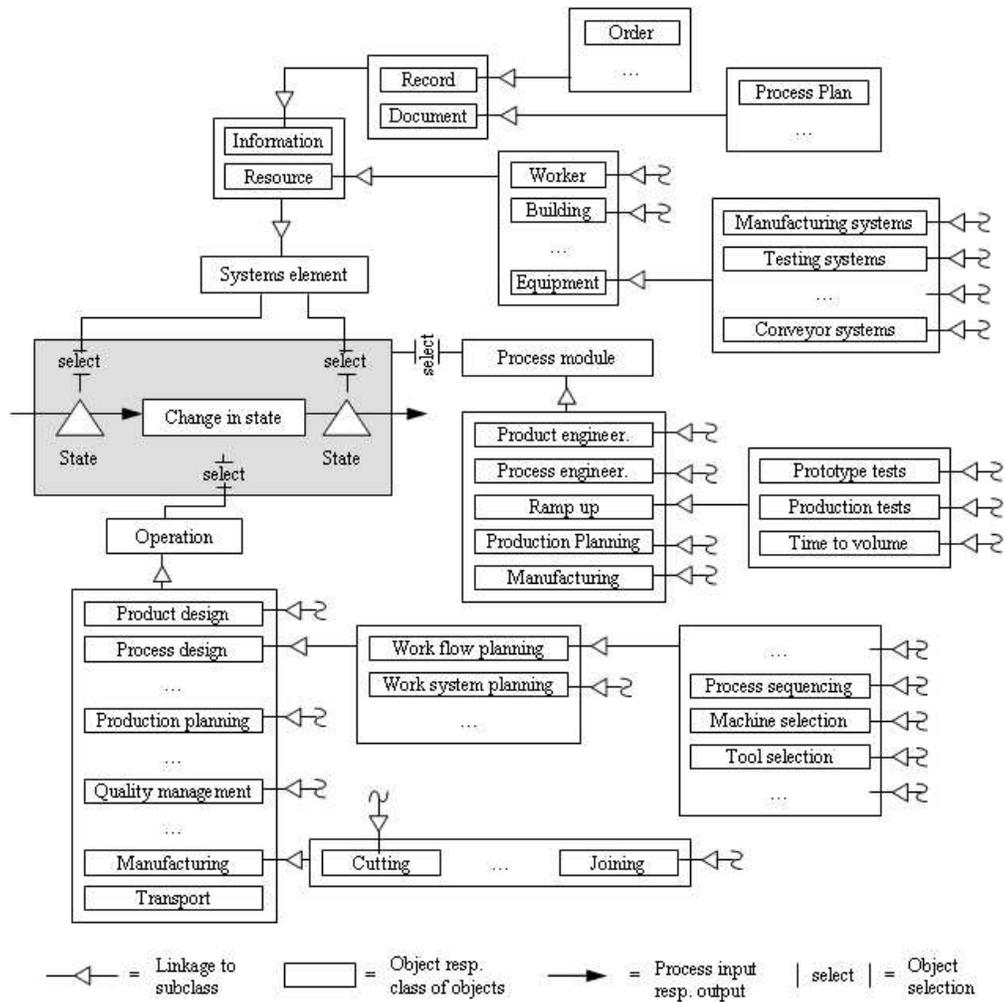


Figure 3: Process modules using the extended IPPM
107x107mm (150 x 150 DPI)

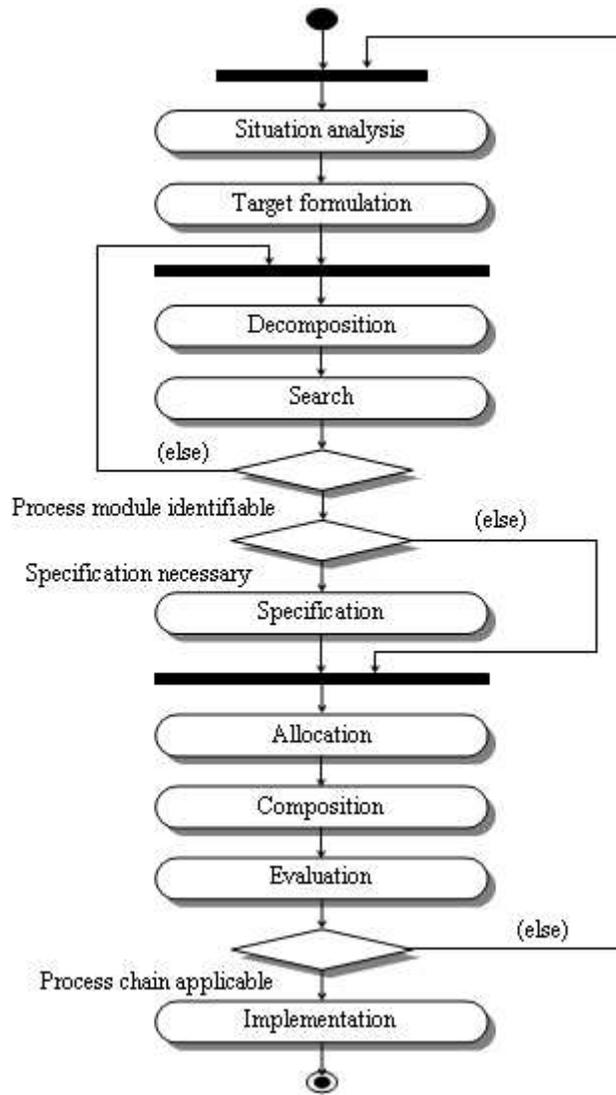


Figure 4: Activity diagram of the design methodology
52x92mm (150 x 150 DPI)



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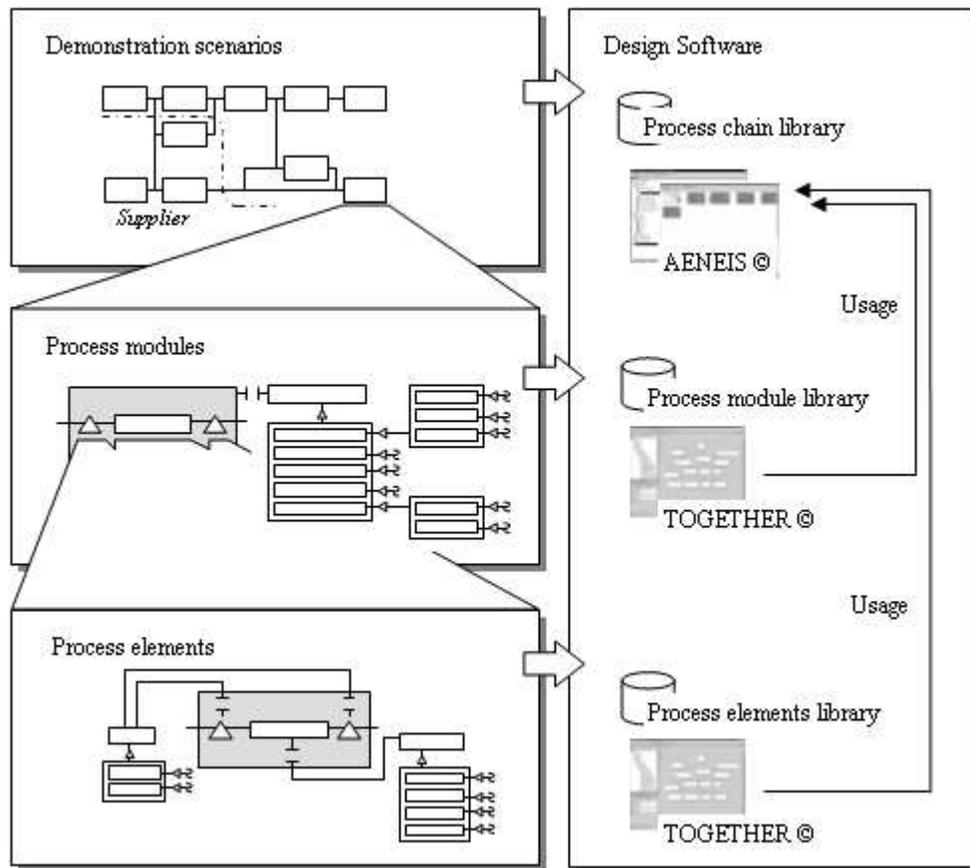


Figure5: Demonstration scenarios and software support
82x73mm (150 x 150 DPI)

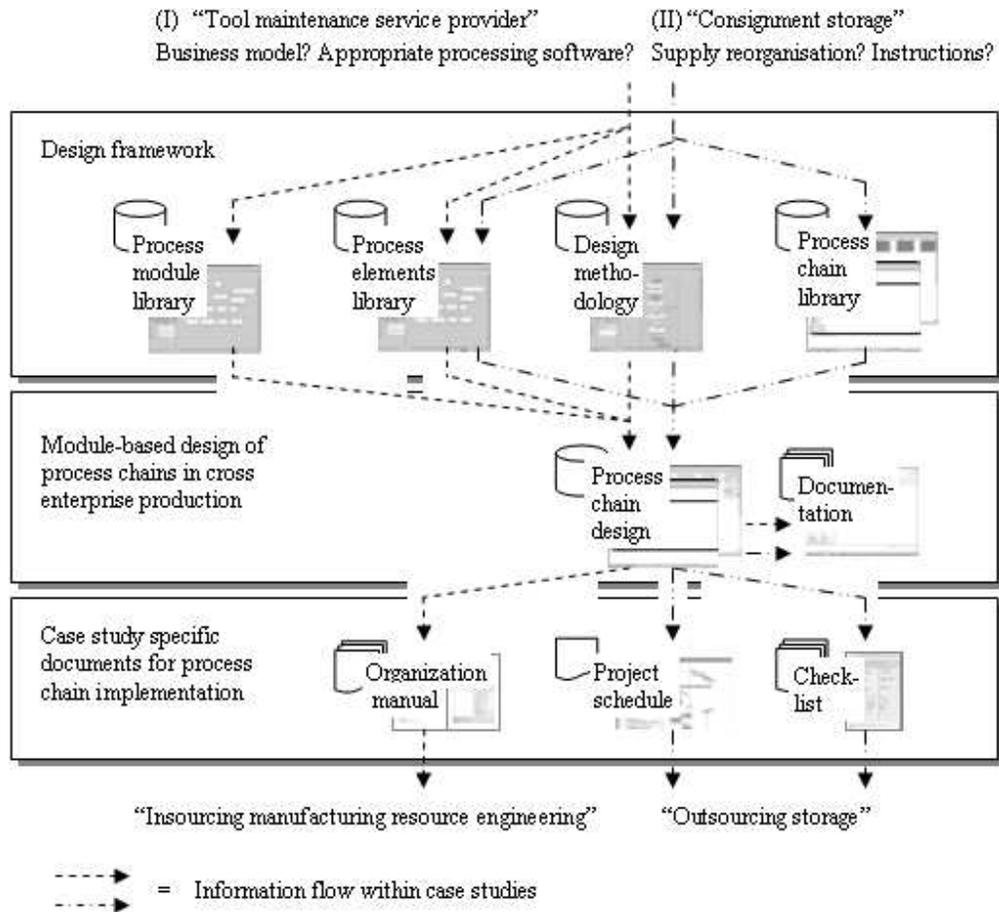


Figure 6: Case studies
86x78mm (150 x 150 DPI)