

# Project and Design Reviews in IPS<sup>2</sup>

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### Abstract

While considerable work has been done in the field of IPS<sup>2</sup> design in recent years, Design Reviews (DR) in IPS<sup>2</sup> context is not given due attention. This work deals with Design Reviews in IPS<sup>2</sup> context as an extension of normal Design Reviews by early stepwise verification of product and service deliveries. Furthermore, IPS<sup>2</sup> Design Reviews differ from normal Design Reviews by continuous customer assessment for combined service/product use. Focusing upon the various stages of generic IPS<sup>2</sup> development processes, Design Reviews are introduced at key milestones and several quality gates of product development. This methodical framework outlines the difference between IPS<sup>2</sup> Reviews and normal reviews by focusing on key IPS<sup>2</sup> specific review criteria, elements, deliverables and participants for successful implementation of Design Reviews at each milestone or quality gates.

### Keywords

Design Reviews, IPS<sup>2</sup>, Product Development, Service Development

## 1 IPS<sup>2</sup> DEVELOPMENT

### 1.1 Introduction to IPS<sup>2</sup> development processes

Industrial product-service-systems (IPS<sup>2</sup>) are individualized, customer-oriented configurations of products and services, which affect each other due to their integrated development and provision [1]. IPS<sup>2</sup> development is triggered by various factors based on organisational requirements of either providing value to the customer in the form of intangible services or being more eco-friendly function provider. The intangible services associated with IPS<sup>2</sup> reward organisations with financial incentives and profitability. Furthermore, value adding services help organisations to see new previously unexplored opportunities and enable them to sustain and compete in cutthroat competitive global markets. Currently, there are numerous development process models which focus on product and service development processes. But these models do not deal with service delivery in detail [2]. The IPS<sup>2</sup> Design methodology proposed by Tim Sadek and E.G.Welp focuses on product and service allocation before they are designed [3].

The factors which associate IPS<sup>2</sup> with sustainability are eco-efficiency and dematerialisation. Some methodologies like the ProSecCo methodology which was funded by the European Union (EU) does not focus on environmental or social aspect of sustainability but instead aims at detecting opportunities for innovation by creating IPS<sup>2</sup> opportunities [4]. The BISS methodology focuses on constructing business models such that the created IPS<sup>2</sup> inherently induce sustainability. None of the methodologies focus on Design Reviews. Design Reviews apart from their customary purpose of reviewing the development of each project stage must also ensure that all the gate criteria associated with IPS<sup>2</sup> are fulfilled. Mueller [5] has developed an IPS<sup>2</sup> "Layer Method" which can be applied mainly in early development phases. The purpose of the Layer Method is to support the clarification of the design tasks as well as the conceptual design phase based on the terminology of Pahl et al [6]. This

approach is used to analyse and synthesise IPS<sup>2</sup> ideas and concepts.

### 1.2 Sequenced stages in IPS<sup>2</sup> development

Arnold Tukker and Ursula Tischner [4] have formulated a practical guideline to IPS<sup>2</sup> development in the frame of the SusProNet project based on extensive practical research. The guideline guides the IPS<sup>2</sup> team by providing systematic methodical approach to IPS<sup>2</sup> development. Design Reviews in IPS<sup>2</sup> are based on this guideline wherein reviews are introduced at key milestones and quality gates of the IPS<sup>2</sup> development. These 5 key stages in IPS<sup>2</sup> development are:

- 1 preparation and introduction;
- 2 analysis on PSS opportunities;
- 3 IPS<sup>2</sup> idea generation;
- 4 IPS<sup>2</sup> design;
- 5 make implementation plan.

The overall approach of IPS<sup>2</sup> development is shown in Figure 1. In the preparation and introduction stage, the project initiator starts the project and sets up the project team. A workshop is conducted and experts from various departments like R&D, product design and marketing are invited. The IPS<sup>2</sup> project is given a title and the project charter is developed. Team members are assigned suitable responsibilities. Project start date and anticipatory end date are also established.

In the second stage, the team selects priority need areas that are most interesting to carry out the IPS<sup>2</sup> project. The existing system is analysed by SWOT analysis and possible windows of opportunities for IPS<sup>2</sup> are identified. The project team then defines relevant market segments and underlying client needs for the specified segment. Starting with the end user, a system map is established by adding main stakeholders and by sketching the flows and relationship between them. The potential problems and opportunities in the system map are identified and decision is taken whether the drafted IPS<sup>2</sup> development is feasible or not.

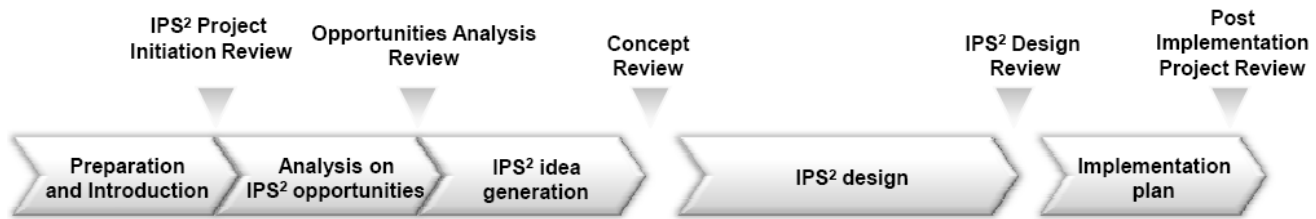


Figure 1 : Overall approach of IPS². [4]

In IPS² Idea generation stage, the team organises a one day workshop in which IPS² ideas are developed by considering underlying client needs and system SWOT report from the previous stage. After a detailed check the ideas are screened for their sustainability potential. The most promising ideas are scored regarding market/ financial potential and capability risks. Based upon the quality of these ideas, decisions are taken to proceed to the next step.

In IPS² design stage, the new PS System structure is formulated by making use of sustainability guidelines. Decision on make or buy is made for external development, production or provision. Furthermore the stakeholder's motivation matrix is developed showing all the partners, their contributions and benefits from the partnership. Finally the decision about proceeding to the next stage is taken.

In the final stage, the project team organises a workshop to specify implementation issues. This phase finishes with a summary of the business plan.

## 2 DESIGN REVIEWS

### 2.1 Introduction to Design Reviews

Design Reviews (DR) can be considered as a type or subset of Project Reviews or Gate Reviews applicable to the product development phase. The primary purpose of Project Review is to keep people informed of reality by providing clear and independently validated information to project stakeholders. Reviews help people to prevent cognitive biases and information bottlenecks [7].

Design Reviews (DR) as an important step in product development process are used throughout the product development process to evaluate the design in terms of costs, quality and delivery- They also help to ensure that most suitable knowledge and technology are incorporated into the design as well as to resolve possible problems instead of passing them downstream. [8]; [9]. Any product or process weaknesses, errors and problems are to be identified during DR. Experts from various departments work together to improve the design efficiency and design time ensuring product quality and minimising costs. Thus, the knowledge and technology are best used from both in-house and external sources. Design Reviews are a mandatory requirement according to the ISO9000 quality standard [11] to verify design at the end of each design output stage of the product development process.

According to Takashi Ichida and Edward C. Voigt [10], reviews follow this basic pattern:

- collecting and compiling information;
- defining quality targets;
- evaluating product and process designs and supporting operations;
- proposing improvements;
- defining subsequent actions;
- confirming readiness for the next stage.

### 2.2 Different Types of Design Reviews

There are two types of Design Reviews based upon their degree of formality in their implementation [9]. Formal Design Reviews (FDR) are reviews for which companies have standard policies and procedures. Each review is a key event in the process of product development and production planning. The development schedule clearly shows designated days for DR within each development phase. The responsible carry them out thoroughly, particularly at the transition from phase to phase. FDR are essential for consistent quality results. On the contrary, Informal Design Reviews (IDR) are prepared and conducted by individual design reviewers. IDR is used only as needed, for example if special issues arise and its effectiveness can vary greatly. It is a review that can be incorporated into any planning and design step as time and resources allow.

### 2.3 Review schedules

According to ISO 9000 [11], the schedule of Design Reviews is established for every developed product or service. The design is reviewed at some or all of the following intervals depending on the complexity of the design and on the risks involved.

*Design Requirement Review* – to assure the feasibility of the design requirements and to reflect the needs of the customer before starting the design phase.

*Conceptual Design Review* – to establish that the design concept fulfils the requirements before project definition commences.

*Preliminary Design Review* – to establish that all risks have been resolved and development specifications have been for each part of the product or service before beginning detailed design activities.

*Critical Design Review* – to secure the compliance of product or service parts with its development specification. The critical Design Review also helps to make sure that product specifications have been prepared before prototypes are manufactured.

*Qualification Readiness Review* – to establish the configuration of the baseline design and readiness for qualification before commencement of design proving.

*Final Design Review* – to establish that the design fulfils the requirements of the development specification before preparation for its production.

### 2.4 Service Design Reviews

Currently, there is no standard literature which focuses on Design Reviews in service context. ISO 9000 [11] describes a generic Design Review which is applicable for both product and services. A typical flowchart for the service design process is shown in Figure 2. Service reviews are incorporated at the requirement stage, conceptual design stage and detailed design stage.

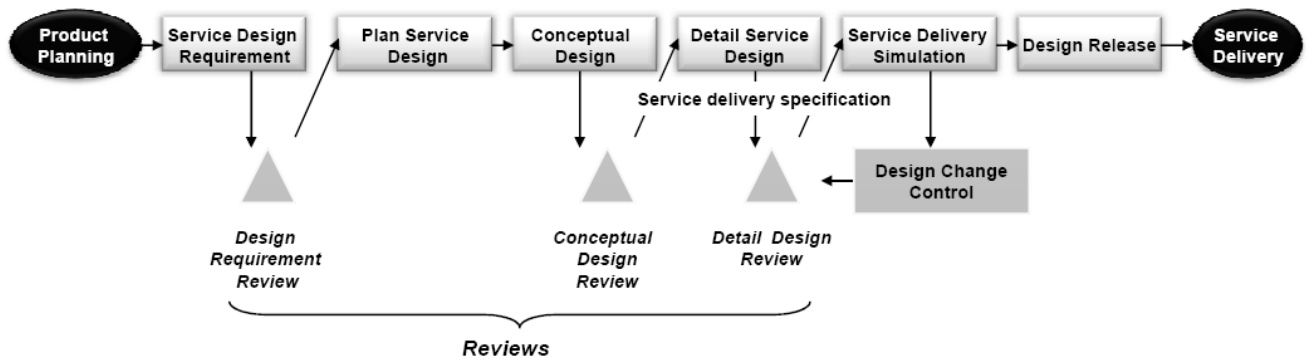


Figure 2 : Reviews in service design process. [11]

### 3 IPS<sup>2</sup> REVIEW PROCESSES

#### 3.1 IPS<sup>2</sup> Development stages

The generic product development consists of following stages as shown in Figure 3. The Review process is conducted in the form of gate reviews at the end of each stage. Thus, the risks associated with the development process are effectively managed. Furthermore, it provides a systematic guideline for holding effective gate review meetings. Usually stage gate systems involve four to seven stages and gates depending upon the company or division [12]. IPS<sup>2</sup> development stages based on practical guideline to IPS<sup>2</sup> development developed by Arnold Tukker and Ursula Tischner [4] have already been shown in Figure 1. Gates at which Design Reviews are introduced in IPS<sup>2</sup> are established by comparing normal product development stages with IPS<sup>2</sup> development stages. Thus, IPS<sup>2</sup> Project Initiation Review, Opportunities Analysis Review, Concept Review, Preliminary Design Review, Specification Review, Final Design Review and Post Implementation Project Review forms the reviews at corresponding gates.

#### 3.2 Assessment criteria for IPS<sup>2</sup> Design Reviews

During the course of the project, the IPS<sup>2</sup> development team may uncover potential problems that threaten the project's viability. This may result in serious changes in project charter or in the cancellation of the project. In order to determine unattractive projects as early as possible and prevent from pursuing them further, the

project is assessed against the relevant gate criteria. As a part of the Gate Review, project members are required to give an update on these criteria. Furthermore, defining gate criteria simplifies the review process and provides methodical approach to the reviewers.

The fundamental idea of assessing a project at each gate is to ascertain whether the stage confirms to the gate criteria. In IPS<sup>2</sup> context, the following criteria have to be defined:

- sustainability;
- product and service delivery;
- value addition;
- financial return;
- strategic alignment

These criteria apply to each gate with varying degree. The explanation to these criteria is as follows:

**Sustainability:** The sustainability factor as per [4]; [13]; [14]; [15] is defined based on the magnitude of environmental impact reductions. Therefore, it is ecologic sustainability only and not taking into account economic and social sustainability elements. They are classified as mechanism leading to average, average to high and very high impact reductions. The activities and decision taken at various stages of IPS<sup>2</sup> development may have profound influence on the sustainability of the delivered IPS<sup>2</sup>. Thus, it is very important to determine the influence of various stages on sustainability. Design Reviews with sustainability elements ensure that sustainability factors

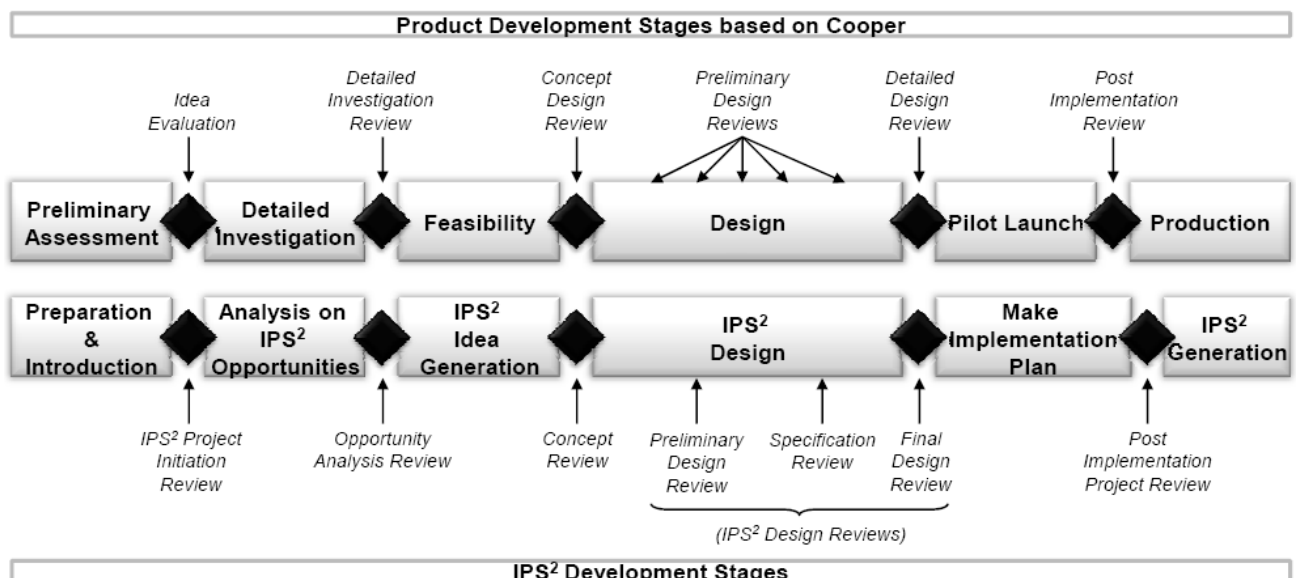


Figure 3: PSS development stages based on Cooper. [12]

are given due consideration at each stage.

**Product and Service delivery:** Design Reviews in IPS<sup>2</sup> context ensure stepwise determination of product and service deliveries. Proper allocation of products and services before they are designed allows partial substitution of product and service components in order to deliver more value to the customer [3]. The purpose of considering product and service deliveries in the Design Review process is to ensure that the design and development of products and the provision of services are planned, reviewed and verified to statutory functions and that requirements of the customers are met [16]. Therefore, the following is necessary:

- Customer needs are determined and reviewed.
- The scope of the products and services has to be clearly understood by the IPS<sup>2</sup> provider.
- Product and project plans have to be developed, communicated and followed.
- Roles and responsibilities have to be clearly defined;
- Where practical and appropriate, consultation and feedback processes have to be undertaken during planning and verification phases.
- Records have to be kept to demonstrate the planning, development and verification of the IPS<sup>2</sup> in accordance with the defined processes.

**Value addition:** The major incentive offered by the organisations to customers through IPS<sup>2</sup> is value addition. The ability to create and capture sustained added value is often seen as the key measure of success in business [17]. Moreover, the customer's willingness to invest in IPS<sup>2</sup> or preference over comparable competing offers is dependent upon the overall value of the IPS<sup>2</sup>. The customer will only decide to adopt an IPS<sup>2</sup> if the overall value of an IPS<sup>2</sup> is positive and higher than that of competing offers [18]. According to Arnold Tukker [17] value addition elements are distinguished as:

- tangible and intangible value;
- an assessment whether intangible value to the customer through servicing outweighs the additional costs borne by the producer;
- an assessment whether investment and capital needs for the IPS<sup>2</sup> generation is justified and
- the ability to capture present value in the value chain, now and in the future.

**Financial Return:** Cost Accounting in the early development phase of IPS<sup>2</sup> helps the development processes in solving decision related problems [18]. Costs incurred in the future have to be adjusted to market conditions to ensure sound investments. Traditional costing methods determine costs for short term only. But life cycle oriented characteristics of IPS<sup>2</sup> with a payment oriented view on costs and revenues necessitate a strategic planning of costs with long term focus. Target costing in IPS<sup>2</sup> focusing on long term promises to solve this problem by enabling life cycle optimisation of the balance between costs and revenues. Assessing an IPS<sup>2</sup> concept therefore needs to be based on the Net Present Value (NPV) of costs and revenues [19]. The advantage of this approach is that the primary decision and payment interdependencies through the IPS<sup>2</sup> life cycle analysis are revealed. This is especially important with regard to interactions of products and downstream services and the payments connected to them. Managing the costs incurred over the entire IPS<sup>2</sup> life cycle is essential to decide whether the supplier aims at gaining profit mainly through servicing or by investing into reliability of the product during IPS<sup>2</sup> conception.

**Strategic Alignment:** Before considering IPS<sup>2</sup>, it is imperative to know if IPS<sup>2</sup> fits company's product line and business strategy. In order to balance both the customer's and the organisation's perspective, corporate structure drivers and customer process drivers are defined [19]. Corporate structure drivers are customer's know-how, resources and organization strategy. Customer process drivers include processes which are significant for the customer's value creation and the frequency in which they occur.

Customers with high a level of know how tend to choose more complex solutions than the latter. Hence an increase in knowledge can be ascribed to choosing automatic rather than manual execution of processes. Similarly, customers with high liquid capital rather tend to choose the automation of processes whereas companies with high labour capital tend to choose the manual execution of processes. Based upon management strategy, organisations can be classified regarding their focus on core competencies. Depending upon core competencies, organisations can decide whether to make or buy. Likewise, organisations can be also categorically distinguished based on their inclination to executing a value based management approach.

### 3.3 Review processes against gate criteria

Figure 4 shows how the project is assessed against gate criteria in between two stages of product development. These criteria are checked at all review stages to determine whether the project adheres to the fundamental IPS<sup>2</sup> idea while being economically viable to the companies. The relevance of these criteria may vary with the review stage and the type of IPS<sup>2</sup>. To ensure that these criteria are given adequate consideration throughout the IPS<sup>2</sup> development process, they are structured as mandatory requirements in Design Reviews. By reviewing through these criteria, companies can be guaranteed that they are not deviating from the main focus of the project and also assist them in deciding whether to proceed with the project or not.

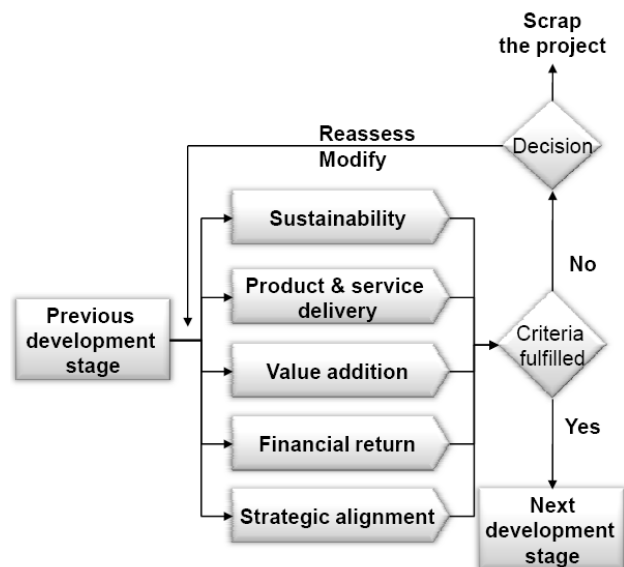


Figure 4: Assessment of the stages against the criteria.

Table 1 shows the relevance of these criteria on Reviews at various stages. The importance of the criteria at each Gate Review is specified on a generic level. The management can thus decide and make suitable amendments to the table to suit their business and management strategy. E.g. companies intending to offer IPS<sup>2</sup> to the customer by delivering more service options without focusing on sustainability can assign more value

Table 1: Gate criteria at various review stages.

<i>Review type</i>	<i>IPS<sup>2</sup> Project Initiation Review</i>	<i>Opportunities Analysis Review</i>	<i>Concept Review</i>	<i>IPS<sup>2</sup> Design Review</i>	<i>Post Implementation Project Review</i>
Sustainability	Preliminary assessment to ascertain whether the IPS <sup>2</sup> solution can be made sustainable or not.	The existing system has to be evaluated using SWOT analysis for its sustainable dimension based on factors like Material efficiency, Energy efficiency, Toxics and Environmental risks, Waste Minimisation, reuse, recycling, Transportation and mobility efficiency.	The proposed IPS <sup>2</sup> has to be assessed for its sustainable dimension based on factors like Material efficiency, Energy efficiency, Toxics and Environmental risks, Waste Minimisation, reuse, recycling, Transportation and mobility efficiency.	Detailed design must have used sustainability guidelines proposed by Suspronet [4].	Assessment to ascertain the degree to which IPS <sup>2</sup> is sustainable.
Product and Service delivery	Preliminary identification of product and service delivery concepts.	The existing system must be evaluated for product and service deliveries.	Integrating product and service delivery based on Heterogeneous modelling approach [3].	Integrated product and service modelling using any approach.	Description of product and service in the final management report.
Value addition	Preliminary assessment of customer needs based on market research; preliminary assessment of competitive solutions and opportunity for differentiation.	Benchmarking competitors. Generate product and service requirements based on voice of customer. Compelling value proposition established.	Update to product and service requirements. Assessment of ability of IPS <sup>2</sup> to meet customer requirements.	Confirmation of fulfilment of value addition elements in Detailed Design to those planned in conceptual stage.	Assessment to ascertain whether planned value addition elements are attained.
Financial Return	Preliminary estimation of the project's viability in financial terms. Break even analysis and Net Present Value can be used.	The existing system has to be evaluated using SWOT analysis for its economic dimension based on factors like market position and competitiveness, profitability, long term business development risk, partnership, cooperation, macro-economic effect and market influence.	The proposed IPS <sup>2</sup> solution has to be compared with existing system based on profitability of provider and customer, savings in time, material use etc. Target costing has to be established. Assessment should be made regarding likelihood of achieving target costs.	Assessment to confirm whether projected costs at concept stage do not exceed target costs.	Assessment to confirm whether costs at implementation stage are below target costs.
Strategic Alignment	Assessment of strategic fit between company's business focus and core competencies. Preliminary justification of resource allotment to the project.	Update on the previous gate regarding assessment of strategic fit and justification of resource allocation.		Decision to make or buy and selection of partners.	

to the product and service criteria than to the sustainability criteria.

As there are numerous methodologies focusing upon service development and IPS<sup>2</sup> development, companies can choose any methodology for designing the IPS<sup>2</sup> based upon their requirement. The developed review methodology is still applicable irrespective of the design methodology employed by the company.

### 3.4 Review processes in IPS<sup>2</sup>

Design Reviews in this work are inspired by Arnold Tukker and Ursula Tischner's practical guideline to IPS<sup>2</sup> development. Even if classic Engineering Design Reviews are not only focused on reviewing individual criteria sets, this goal is even more eclipsed in IPS<sup>2</sup> reviews. Keeping alignment on delivering the target values of IPS<sup>2</sup> delivery between the different stakeholders during the development, issue escalation, design compromises, the

creation of task forces were needed and the steering of operational execution of design amongst all partners, including the new partners such as clients, service members and so on, is more in the focus here and is even more difficult into the bargain. All those issues are subject matter of any IPS<sup>2</sup> review and are therefore not mentioned as specific goals for single review types.

In order to identify the importance of Design Reviews on their underlying stages, it is imperative to understand the basic activities of the corresponding stages. The Reviews identified based on this guideline are:

- IPS<sup>2</sup> Project Initiation Review;
- Opportunities Analysis review;
- Concept Review;
- IPS<sup>2</sup> Design Review;
- Post Implementation Project Review.

In subsequent sections each review process is explained by describing the activities of the respective stage, entry requirements for the review process, tools used, deliverables and participants of the review process. Entry requirements refer to the possible documentation that is required before the start of the review process. Criteria checklist is a report confirming that all the criteria that are listed in section 3.2 are fulfilled. The major difference between the IPS<sup>2</sup> reviews with the conventional reviews is the participation of customers and the provision or commissioning department. Although the participation is not listed as mandatory in the individual review stages, they can still take part actively based on the IPS<sup>2</sup> requirements.

### 3.5 IPS<sup>2</sup> Project Initiation Reviews

The IPS<sup>2</sup> Project Initiation Reviews correspond to the "Preparation and Introduction" stage. The major activities in this stage are planning the project, setting up the project plan and familiarising team members with IPS<sup>2</sup> concepts. The Initiator starts the project and sets up the project team. A project charter is developed by deciding an IPS<sup>2</sup> project title. Appropriate responsibilities are assigned to the team members. The project start date and anticipatory project end are also established. Normal project planning tools can be used during this stage. A workshop is conducted to educate the team members about the benefits of the IPS<sup>2</sup>. The project definition is the mandatory entry requirement to the IPS<sup>2</sup> Project Initiation Review.

**Goals:** The primary goal of IPS<sup>2</sup> Project Initiation Reviews is to secure that all team members and stakeholders are familiar with the concept of IPS<sup>2</sup> in general. It has to be ensured, that the project charter for the pre-design phases is fully developed and all responsibilities are assigned. The reporting structure has to be reviewed concerning the deliverables of project stakeholders. This sets the kick off for IPS<sup>2</sup> opportunity analysis.

**Deliverables:** Project/ program/team charter, program requirements/ deliverables, budget approval, project timing, quality goals (if applicable), project tracking, a record of workshop held for familiarising team with IPS<sup>2</sup> concepts, criteria checklist are the deliverables of the review process. The criteria checklist ensures that factors such as sustainability, product and service delivery, value addition, financial return and strategic alignment are reviewed at this stage.

**Participants:** The participants required for the review process are the planning team, departments responsible for controlling, project management, product and service development as well as the customers.

### 3.6 Opportunities Analysis Reviews

The Opportunities Analysis Reviews correspond to the "Analysis on IPS<sup>2</sup> opportunities" stage. The major activities in this stage are selecting priority need areas, analysis of the existing system, analysing client needs, drafting system map and finally making decisions regarding the continuation of the project. Using priority setting matrix, the need areas are selected by the project team. Then, system SWOT is carried out for the current and future situation in the need area and key problems, drivers for change, and windows of IPS<sup>2</sup> opportunities are identified in the system. Economic, environmental and social inefficiencies are also identified during this process. For the selected area, relevant market segments and their underlying client needs are identified by the project team. The system map of the current system showing various actors and activities, financial flows, information, important problems and opportunities is drafted. In the end, the project team decides on the continuation of the project.

The project charter is the mandatory entry requirement to the Opportunities Analysis Review.

**Goals:** In the Opportunities Analysis Review the analysis of needs of the customer has to be reviewed. Furthermore, the SWOT analysis report and the market analysis have to be verified. In the end there is a go or no-go decision for the next stage.

**Deliverables:** Priority matrix, 5 why analysis report, CT trees or QFD, SWOT report with environmental, socio-dimensional and economical dimension, system maps, information flow diagram, process flow diagram, decision sheet and criteria checklist are the deliverables of the review process.

**Participants:** The participants required for the review process are the planning team, marketing, departments responsible for controlling as well as the product and service development.

### 3.7 Concept Reviews

The Concept Reviews correspond to the "IPS<sup>2</sup> Idea Generation" stage. The major activities in this stage are generating IPS<sup>2</sup> ideas, checking the completeness of generated ideas, describing ideas, selecting priority ideas and finally making decisions regarding the continuation of the project. This stage is conducted as a one day workshop. At the start IPS<sup>2</sup> ideas are developed by taking underlying client needs and the system SWOT. Creativity tools like brainstorming, sustainability guidelines and consumption cycle analysis can be used. Using IPS<sup>2</sup> innovation matrix, the team performs a check if the most relevant ideas have been generated. Then the ideas are described in a one page IPS<sup>2</sup> description format. Using IPS<sup>2</sup> sustainability screen, the ideas are screened for their sustainability potential (economic, environmental and social). The ideas are filled into the portfolio diagram to select the most promising ones. IPS<sup>2</sup> ideas are scored against market/financial potential and the final decision is taken regarding the continuation of the project. The stage 2 decision sheet is the mandatory entry requirement of the Idea Generation Review.

**Goals:** The generated conceptualised IPS<sup>2</sup> solutions should be consolidated to one single concept of the IPS<sup>2</sup> that shall be designed. Therefore, the concept has to be verified and validated with the customer.

**Deliverables:** Brainstorming records, IPS<sup>2</sup> innovation matrix, IPS<sup>2</sup> description format, IPS<sup>2</sup> sustainability screen, portfolio diagram, Go/ no-Go scoring system, criteria checklist are the deliverables of the review process.

**Participants:** The participants required for the review process are the planning team, departments responsible for controlling, product and service development as well as the project management and the customer.

### 3.8 Preliminary Design Reviews

The Preliminary Design Reviews correspond to the "Concepts and preliminary design for subsystems" stage.

**Goals:** In the Preliminary Design Review, the preliminary design has to be verified for its robustness and quality. The approval from change engineering department has to be reviewed in case of any design changes.

**Deliverables:** Deliverables are Design Tools, Go/no-Go evaluation criteria and criteria checklists.

**Participants:** The participants required for this review process are the planning team, departments responsible for controlling, product and service development as well as the project management.

### 3.9 Specification Reviews

The Specification Reviews correspond to the "Specification of product, service and IPS<sup>2</sup> modules".



**Goals:** In the Specification Review, the specification of the product, service and IPS<sup>2</sup> modules have to be verified. The approval from change engineering department has to be reviewed in case of any design changes.

**Deliverables:** Design tools, specification standards, Go/no-Go evaluation criteria and criteria checklists are the deliverables of the review process.

**Participants:** As participants for the review process, the planning team, the departments responsible for controlling, product and service development as well as the project management are required.

### 3.10 IPS<sup>2</sup> Final Design Reviews

The IPS<sup>2</sup> Design Reviews correspond to the “IPS<sup>2</sup> design” stage. The major activities in this stage are concluding design, deciding on make or buy issues, selecting additional partners where needed and finally making decisions regarding the continuation of the project. The new IPS<sup>2</sup> system structure is worked out and the detailed design of the system is carried. Sustainability guidelines can be used in design process. System map is developed by mapping activities and material flows, information flows and financial flows. The decision regarding make or buy is taken and potential partners are identified for the elements not produced by the own firm. The assessment about how to proceed is made and implementation plan is formulated. The stage 3 decision sheet is the mandatory entry requirement of the Detailed Design Review.

**Goals:** Goals of the Design Review are to verify the IPS<sup>2</sup> products and services as well as the dependencies between them on a technical level. Decisions on make-or-buy, manufacturing location and service partners have to be taken. The final business model as well as first contract drafts have to be verified and validated too.

**Deliverables:** Solution element brief, make buy decision sheet, stakeholder motivation matrix, Go/ no-Go evaluation criteria, criteria checklist are the deliverables of the review process.

**Participants:** The participants required for the review process are the planning team, departments responsible for controlling, product and service development as well as the project management.

### 3.11 Post Implementation Project Reviews

The Post Implementation Project Review corresponds to

the “Develop implementation plan” stage. The major activities in this stage are defining implementation issues and summarising management presentation. A workshop is organised by the project team to specify implementation issues. The stage ends with a business plan and presentation which summarises the project. The stage 4 decision sheet is the mandatory entry requirement of the Post Implementation Project Review.

**Goals:** The concrete implementation of the IPS<sup>2</sup> has to be reviewed in this process. All documentations for the manufacturing and provision processes have to be completed and reviewed. The milestones for the start of production and provision have to be determined in a decision by consensus of all stakeholders, especially the producers, customer and service providers.

**Deliverables:** Standard management presentation, criteria checklist are the deliverables of the review process.

**Participants:** The participants required for the review process are the planning team, departments responsible for controlling, product and service development as well as the project management. Furthermore, the production manager, the service provider and the customer have to be present.

### 3.12 Draft of IPS<sup>2</sup> development process

The milestone based reviews can be applicable to Mueller’s draft of IPS<sup>2</sup> development process also. Figure 5 shows the synergies between Tukker’s and Mueller’s approach to IPS<sup>2</sup> development. In Contrast to the Tukker methodology which focuses extensively on the stages prior to the design, Mueller’s methodology mainly deals with the design phase. Furthermore, Mueller’s development stages ranging from the preliminary design to the final design of IPS<sup>2</sup> can be clustered under Tukker’s IPS<sup>2</sup> design stage. Therefore, IPS<sup>2</sup> Design Review comprises of the following reviews:

- Preliminary Design review;
- Specification Review;
- Final Design Review.

The gate criteria are applicable to these design stages. The relevance of the gate criteria is comparatively higher than in the preceding reviews.

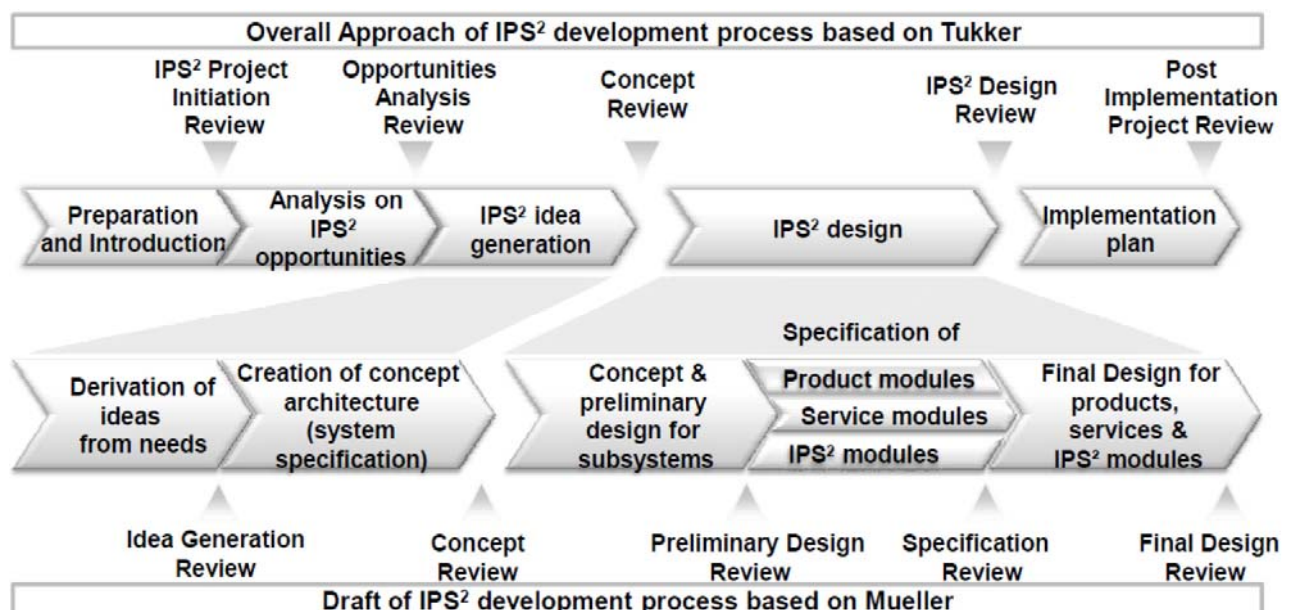


Figure 5: Reviews in IPS<sup>2</sup> development.

#### 4 OPEN ISSUES AND FURTHER RESEARCH

This Paper has so far addressed the development of an IPS<sup>2</sup> Project and Design Review guideline for including reviews in the IPS<sup>2</sup> project milestone schedule. It has intentionally not yet elaborated on the Design Review process itself, therefore, it is a lot about “what” and not very much about “how”. This is going to be the next step in our research work. An incomplete list of open questions shows the complexity of issues still to solve in this context:

- How can the stage of IPS<sup>2</sup> development be verified?
- What are the dependencies between product and service components in IPS<sup>2</sup> development and how do they influence the business model, the IPS<sup>2</sup> provider consortium or single stakeholders’ interests?
- How can these very dependencies be taken into account when decisions are made?
- How can the complex interdependencies of products and processes in IPS<sup>2</sup> be brought down to a level where stakeholders from different areas of expertise can have a discussion that is still valuable enough to make robust and sustainable decisions?
- How can experiences from the IPS<sup>2</sup> provision phase be incorporated in further developments?
- How can a roles and responsibilities concept for the different Design Review types look like?
- What are the necessary actions for effectively and efficiently preparing, carrying out and reinforcing IPS<sup>2</sup> Design Reviews?
- How can IPS<sup>2</sup> Design Review processes be computer aided without overstraining the stakeholders with elaborate user interfaces?
- What functionalities are necessary for such a system to provide essential assistance to the Design Review process?
- Is the Design Review still a scenario for the future or might it be replaced by the long predicted collaboration workspace where everybody is working and developing with the very same model all the time?

Those open questions have been focussed on in our current research work. First results are already in sight.

#### 5 CONCLUSION

This work gives a generic guideline to the implementation of Design Reviews during IPS<sup>2</sup> development. This guideline is applicable to any IPS<sup>2</sup> development irrespective of the development methodology used. As this work is a first step towards installing IPS<sup>2</sup> Reviews as a core process step in IPS<sup>2</sup> development, there is ample scope for further research. As Design Reviews are directly dependant on product development processes, it is essential to have a common IPS<sup>2</sup> development methodology which can be universally used. Further work in this regard could be directed at developing specific review methodologies for specific types of IPS<sup>2</sup>. Web based reviews are currently very popular in Software Design Reviews. Developing similar web based solution for IPS<sup>2</sup> Design Reviews could also be a worthwhile proposition for the companies providing IPS<sup>2</sup>.

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