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EVOLUTION MODELLING AND PROBLEM CENTRED DESIGN OF MANUFACTURING SYSTEMS

GEISKOPF F., KIEFER F., CAILLAUD E., VILLENEUVE F.

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1 Introduction

The industrial problems associated to this paper deal with the introduction of a new manufacturing technology in an existing manufacturing system. We aim to assist designers in assessing the relevance of the new process (High Speed Machining, HSM, in particular), in the early stages of the manufacturing system design. Therefore the design method proposed in this paper includes a global conceptual analysis of the situation and links to the process features to be implemented. The first aspect enables a complete analysis whereas the second one, which is seldom treated, is essential to support efficiently the choice of a new process. This method, called PIA (Problem Integrated Approach) leads from the definition of the objectives to the detailed specifications of the future system (including the technical, organisational and economical aspects). PIA is based on the concurrent engineering principles and a dialectic approach of system modeling. Problems of the actors of the system are reformulated to design a target system architecture. To support this phase, a generic problem framework is defined (partially presented) and applied during a specific design process.

2 Concurrent engineering in early stages

2.1 Early stages of system design

The early phases of the design process have received relatively little attention, even though decisions made during this period have the most far-reaching effects on the remainder of the product development. It is necessary to overcome the informal aspects, the lack of organization, the darkness of the structure of these phases which make them difficult to model.

In order to fulfill this, Girard [1] proposes to analyze the previous product developments and to make decisions regarding the requirements definition. It enables to ensure the product feasibility, during its early phases. In Grabowski's view [2], the early phases list, in details, all the specifications. These include internal specifications (from the inside of the company) or external ones (from the customer); implicit ones (main functions) or explicit one (technical functions); complex or simple ones depending on the ability to decompose them; “fixed” or “desired” ones if they are qualified by “need to have” or “nice to have”; quantitative or qualitative. Design projects are based on requirements definition or on specifications.

The preliminary design may be defined as the whole process stages when the problem is built and the research of principles goes all way through. It results in the requirements definition or in the specifications formulation. Nevertheless, the inaccuracy or vagueness of this definition highlights the lack of formalisation in this domain. Even if their stakes are important, early phases of the design process remain barely modelled.

Good practices required during the early stages of the engineering design have to be identified, from a global point of view, thanks to a state of the art in the next part of this paper. Then, considering manufacturing systems as a product, the related practices are discussed in order to position our contributions.

2.2 Concurrent engineering

Several points dealing with concurrent engineering are widely demonstrated in academic publications and applied industrially. From the literature, three properties are to be taken into account for our further work, centered on the early stages of a system design.

Firstly, Girard [1] clarifies the pluridisciplinary interaction in the context of customer/provider transactions. In this boarder, engineering design consists in 'synchronising the product knowledge with the customer's needs knowledge'. In other words, Lonchampt [3] compares it to a transformation process, which translates customer needs into a product definition.

Secondly, the pluridisciplinary nature of design activities is widely demonstrated. The need to embody all aspects of the product life cycle explains this fundamental characteristic of design. For example, Lonchampt [3] demonstrates that designing implies to link entities (people, objects, and knowledge) which can not be determined before. The integrated design approach, or concurrent engineering, proposes to achieve this task by integrating these multiple points of view into a multidisciplinary team.

At last, in order to succeed in sharing the knowledge about the customer's needs, the design team members must have the ability to communicate, according to Prasad [5]. The project team must be able 'to switch between different aspects of the present job and to develop concurrent working patterns' to increase the efficiency of the process.

The communication between the team members becomes thus an essential stake. Prasad states that this kind of approach has to follow a concurrent product development mode, instead of a serial one. That is to say, the workflow (the flow of product, work, organization, and resources along the process) moves between the different disciplines, or the workgroups, and the phases of the process. Cooperation is the key feature of a concurrent workflow management process. Roucoules [6] interprets these principles and set the properties of such a design process. During the design process, each actor must:

- Reach all information concerning the designed product, along the process;
- Be able to use his own tools to be efficient;
- Have a specific view of the product and use his own language;
- Have translations commodities to understand all other participants;
- Be able to insert his own constraints to design the product.'

Thus, an integrated design process has to take into account the duality between the communication of pluridisciplinary team, and the job of each designer in his specific discipline. This conflict is now studied in the field of the design of manufacturing systems.

2.3 Manufacturing System specification

The structure of our analysis is based on a state of the art centred on systemic design approaches and, particularly, the GRAI models and methodology, for which Ducq [4] proposes a synthesis. This reference architecture in the field of enterprise modelling has proved its efficiency in manufacturing system design as well as in design process modelling. Knowing the state of a manufacturing system at a given moment (current or future) implies to know about the following aspects of the system: its functions, its components, and its performances.

- Functional point of view of the system.

Concerning manufacturing systems, the Production System Design (PSD), introduced by Cochran [7], represents a generic framework, modeling the principles of Lean Manufacturing. It maps Functional Requirements, Design Parameters, System variables, in relationship with the customer field (the needs, the constraints...). The GRAI models identify three classes of functional activities of decision systems within manufacturing systems: the product management activities, the planning activities and the resource management activities. Though these theories intend to be applied during the conceptualization stages (i.e. early stages of design), they do not clearly state how the designers and the future users of the system cooperate during the process. However this cooperation is a key feature of concurrent engineering, as related before. The functional point of view is necessary to define the objectives of the detailed design (at a conceptual level), but has not already proved its efficiency in terms of mutual comprehension.

- Component point of view of the system.

Within the systemic approach, defining the components of a system means specifying human resources, physical components, and their relationships. This set of concrete elements defines the system architecture. By definition [8], the system architecture details the set of components with assigned objectives (Which are the components ?), their temporal interactions (When do they interact ?) and their spatial interconnection (which are their relative position ?). On the one hand, the concrete aspect of the architecture definition makes it easily understandable by all the actors involved in the design process. On the other hand, the conceptualization required in the early stages can not be based entirely on such a concept, as it has been demonstrated before.

- Performance point of view of the manufacturing system.

As developed in Ducq [1], an objective, fixed in the early stages, expresses the intention of moving from an existing performance status to the expected performance status for the physical system, controlled by a decision center. This objective must be expressed with a verb explaining the expected trend (i.e. to increase, to decrease, to maintain) associated to a considered performance domain (i.e. cost, quality, lead time, flexibility). So, during the conceptualization phases, the objective value of the performances of the system must be set. Paradoxically, none of the reviewed generic design methods links performance to functions of the systems nor to its components.

Finally, two aspects may be synthesized. The relationships between these three fundamental concepts are barely formalised in the literature. Very few methods are based on all of them. The only methods which intend to are GRAI-GIM and PERA, the manufacturing system design method of Purdue Laboratory. both methods do not emphasize the necessity of cooperation between all the stakeholders through the design process, even during the conceptualization phase. Secondly, concerning the system modeling, this couple of methods remains at a high level of genericity. Their instanciation to a class of process or a particular shopfloor may need to spend a lot of time, because of the extent of the field of technical and organizational solutions. The related manufacturing system models are not accurate enough to assess the potential of a new process to be implemented.

The next section aims at presenting the reference models and methods used to fulfill the lack of cooperation in the early stages of manufacturing system design (during the conceptualization phase) and of process oriented models.

3 Problem and system evolution

Our scientific problems can be resumed as follows :

- Make designers cooperate and communicate during the early stages and allow each one to be efficient in his particular domain. So, the specific points of views are to be shared during the process, especially at the conceptual level;
- Link the functions of the system, its performances to the specification of the architecture of the 'to-be' system. This means that organisational models may be used during the design stage to respect the concurrent engineering best practises.

As it is acknowledged that 'talking about problems' (or inconsistencies and dysfunctions) works in preliminary phases [10], our idea and the associated difficulties, are:

- Use a 'problem view' to audit the current situation at the conceptual level;
- Design the architecture of the target system, from a common model, based on the same problem view;
- Check and guarantee the coherence of the entire system, in each specific domain, all along the design process.

A state of the art shows that no theory directly related to the design of manufacturing systems proposes such properties. The only we have identified is called OTSM-TRIZ (Khomenko [9]). This theory aims at solving general types of problems appearing in a particular system. We have tried to apply it to a more generic class of systems (manufacturing systems), and to formalise the models (with UML, Unified Modeling Language) in order to be able to design their architectures. We first briefly introduce the framework and then explain the way a problem is perceived along this approach.

3.1 Reference framework

The OTSM-TRIZ framework introduces for each identified function of the system three levels of contradictions. They link the concepts of performance, parameters, and variables. The reference model can be represented, using UML class diagram rules, as shown on Figure 1. According to this framework, a problem appears when one of the two elements of performance of a function of the system can not be improved without decreasing the value of the other one. So the elements of performance model the consequences of the problem. The couple of parameters, defined for each element of performance, are the reason why the problem appears. At last, the variable of the system, appearing in the physical contradiction and associated to the corresponding couple of parameters, emphasizes the impossibility to solve the problem without any evolution of the system. For the value of the element performance in contradiction, the variable must have simultaneously two opposite values.

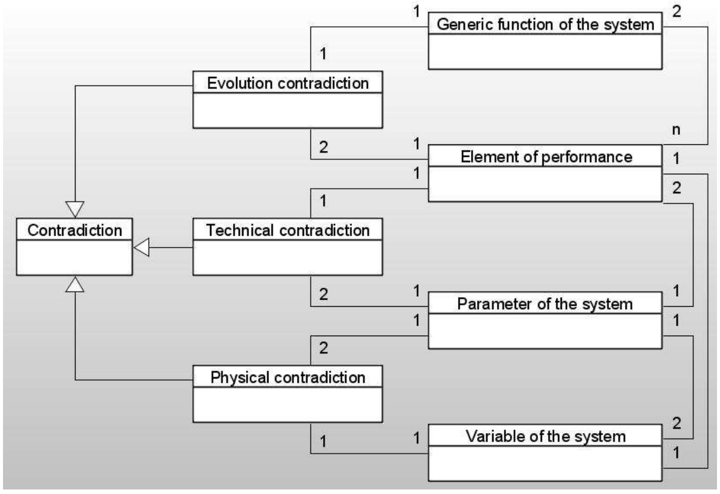

Figure 1. UML Class diagram of OTSM-TRIZ reference framework

OTSM-TRIZ is based on the principle that to each problem corresponds an evolution contradiction. The next section details how we have integrated, in our models, the concept of problem to design an architecture of the system.

3.2 Problem interpretation

As, the problem view has already been introduced before, we intend to build the system architecture on the problem view. As the decision centers are implied in the design process, all kind of related problems (operational, organizational, and strategic) have to be transposed at the conceptual level. This problem reformulation leads to specify the objectives of the design stages. Thanks to this reformulation, two kinds of coherence analysis are performed during the design process:

- By checking if all the problems are taken into account at the conceptual level, the coherence of the objectives is assessed. This means that the local performance achievement contributes to the achievement of the global performance (as defined in Ducq2001).
- By checking the coherence of the results provided by the different disciplines involved. This means that each problem must be solved, respecting the target architecture previously defined during the process.

On the one hand, a problem is linked with several contradictions: evolution, technical and physical contradictions. On the other hand, it is associated to some components of the system. That is why, we have developed a specific model of the system architecture, called 'MSOP' (French acronym for model of operational manufacturing system).

The proposed model provides the generic components of a system and an accurate framework of the set (process - resource - product), in order to formulate the problems. It enables to link problems and process features in order to support the assessing of a new process to be implemented. The model structures generic activities (which are not detailed in this paper) in hierarchical levels, as follows:

- Level 1: Material Removal – Cutting Tool – Chip
- Level 2: Machining Operation – Tool Holder – Surface
- Level 3: Machining Sequence – Fixture – Part
- Level 4: Machining Set-up – Machine-Tool – Batch

Each of these four processes are linked with temporal and spatial relationships. For example, the processes 'material removal' and 'machining operations' are coupled with the architecture of the tool trajectory (the temporal relationship between them). So, after identifying the 'consequences' of the problem (association between the 'Problem' class and the 'Contradiction' class), its 'location' can be established (association between the 'Problem' class and the 'Level of MSOP' class). These two associations of the 'Problem' class are shown on Figure 2: a problem may only be located at a maximum of four levels and may correspond to three contradictions.

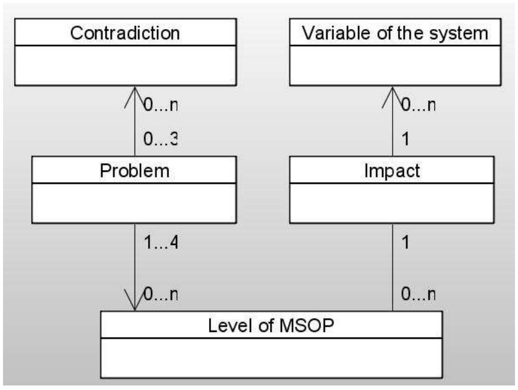

Figure 2. UML class diagram of problem association

The study of the consequences of a problem is based on the generic model of a problem at the conceptual level. This model is the so called 'evolution contradiction'. It highlights the conflict between two elements of performance, of a given function of the system. For manufacturing systems, three functions have been identified.

- The 'Satisfy a given Return on Investment' function; 'Inflows' and 'Outflows' of the manufacturing system are the two financial elements in conflict for this function (Contradiction 1).
- The 'Manufacture Quality Products' function; 'Product Accuracy' and 'Product Delay' are the two elements in conflict for this function (Contradiction 2).
- The 'Manufacture various Products' function; 'Flexibility' and 'Reactivity' are the two elements in conflict for this function (Contradiction 3).

That is why, the multiplicity of the association between the classes 'contradiction' and 'problem' can vary between zero and three (see Figure 2.). So, a problem appearing in a manufacturing system can only be (at the conceptual level) a problem of accuracy, delay, flexibility, reactivity, outflows and inflows, located at some of the four levels of the MSOP. The next section will develop how to use problems to set the objectives of the design process.

This generic problem framework is also applied to build a target architecture of the system, including new elements of technology. The associations between the three classes 'variables of the system', 'impact', and 'level of MSOP' help to explain how problems are exploited to design. An evolution of the physical resource technology has a certain impact which can easily be coupled with a level of the MSOP. The 'variable of the system' class appearing in this diagram is the same as the one in Figure 1. This association between variable and impact allows to link the types of solutions to a problem. Indeed, the reference framework, and the proposed instantiation to manufacturing systems, directly join problem at a conceptual level (in the form of evolution contradiction) to variables of the system (features of the process, for example).

4 Design Process of PIA

This section aims at introducing some aspects of the dynamical view of the proposed design method. These aspects are centred on the way problems are shared along the process.

4.1 PIA Use cases

Figure 3 describes the specifications of the design method to be introduced. On the basis of Use Case diagram rules, the categories of actors implied are listed. The main aim of PIA (Problem Integrated Approach) is to support the shopfloor director, by providing him a complete model of impacts. As problems are handled, the required evolutions (to solve these problems) are consolidated. These requirements are also specified quantitatively, in understandable terms. So, the concurrent approach of PIA is performed.

Figure 3 is already applied to a specific process within manufacturing systems (High Speed Machining, HSM).

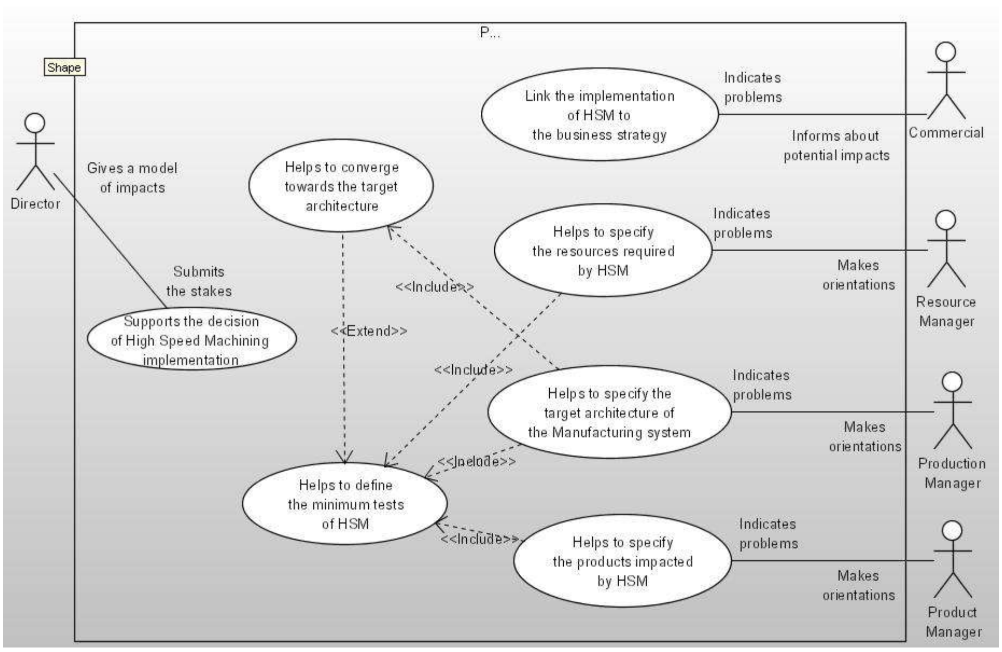

Figure 3. Use Case diagram of PIA

The other actors involved in the process correspond to the three main classes of manufacturing system managers, referring to GRAI models, already cited before. They correspond to the 'manage resources', 'manage products' and 'synchronize' functions. The 'commercial' actor represents all decision centers outside from the shopfloor, who can transmit problems coming from the sale of products.

PIA is a complete design method. That is to say, PIA includes of course the use cases, but also the models (shortly presented in the past section), and the design process (detailed in §4.2). Two models are used : the model of problem which is the instanciation of the OTSM-TRIZ framework to manufacturing systems and the MSOP, which is a process oriented reference architecture of operational manufacturing systems. During the method application, the models are shared at three levels of abstraction:

- Conceptual level: problems as evolution contradictions are the result of the abstraction stage. Processing and sharing problems make people cooperate during this first stage.
- Organisational level: model of the target system architecture. The definition of this architecture allows all disciplines involved in the design stage to check the coherence of their results, according to the structure of the system. This is guaranteed as the architecture already includes concrete elements of the future systems.
- Operational level: the same models are used to design physical and numerical tests (design, develop and realise). These are required to fill the lack of knowledge about the new technology to be implemented. So, PIA helps to design the minimal set of tests required to give all elements, in order to assess the choice of the target architecture (including for example a new manufacturing technology).

4.2 Design of an architecture of the system

The design process represents the dynamical view of PIA. The process, based on problems processing, aims at designing a target architecture of a manufacturing system. It spans four phases:

1. Interviews, and problem reformulation;
2. Understand and explain phenomenon, by formalising technical contradictions;
3. Identify a relevant subset of the manufacturing system (a part for example), thanks to contradiction intensification;
4. Design the target architecture, thanks to 'extreme architectures'. These are based on the intensification principle and on a feasibility analysis concerning the relevant subset.

As the intensification principle is applied in the last two phases, they are deeply based on this specific reasoning. This principle consists in modelling the negative or positive effects of the problem, through their exaggerated modes. Absurdity is advised during this design subprocess, in order to make the problem core appear. Such reasonings should guide the designers towards the relevant evolution of the system.

Figure 4 synthesises these four first steps of the design process. The rules of UML activity diagram have been applied. The following steps, leading to the final system architecture, will be summarised at the end of this section.

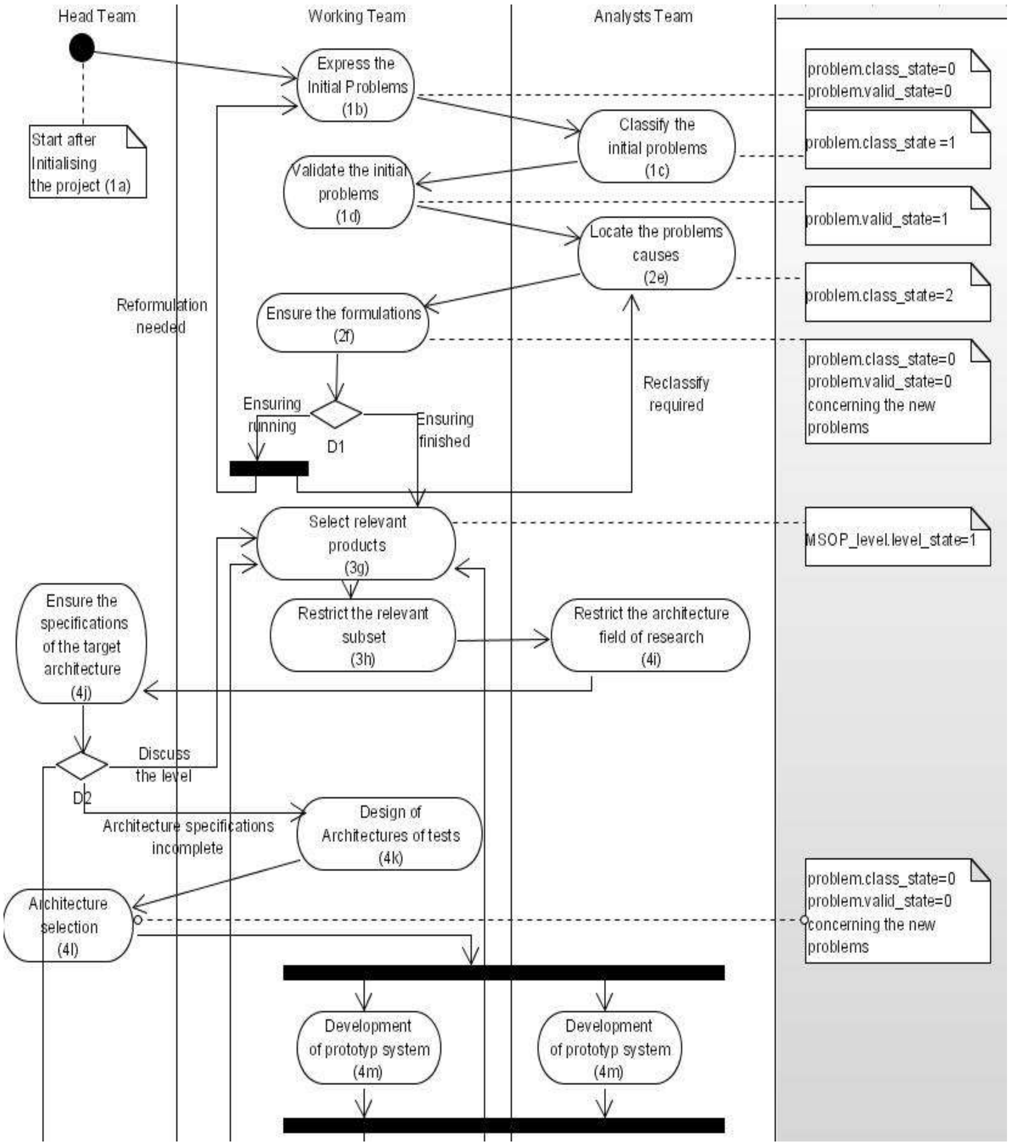

Figure 4. Activity diagram of the first four steps of the design process

Phase 1: Problem reformulation

All the process is based on the problem reformulation. During this phase, all the members involved in the design have to cooperate in order to enumerate all the problems. This activity spans the following steps:

- 1a: Initialisation

The Head Team decides to begin the project, because of bad performances. This team contacts the analyst team, which does not belong to the shopfloor, in the current state of the method. Together, they choose the interviewees, according to GRAI-GIM (GRAI design methodology) criteria: the members must be representative of all decisions centers of the particular manufacturing system.

- 1b: Express the Initial problems

Interviewing the actors about their problems must highlight the acknowledged contradictions in their manufacturing system. The generic framework briefly presented in section 3 allows to guide the interview. This interview can be non structured (spontaneous expression of problems) or structured, by asking, for example: 'do you have problems with one of the six elements of performance, or for a given resource/product couple ?' This step results in a set of initial problems. Along this step, all the problems are shown to all the members, so that every one can continuously modify or complete the different points of views.

- 1c: Classify the initial problems

This classification depends on the concerned element of performance, namely the consequence of the related problem. This work is done by the analysts team, outside of the workgroup. The set of problems is transformed in couples [problems, elements of performance].

- 1d: Assess the initial problems

The result of the previous step is exploited with the workgroup to assess the links between the set of initial problems and the elements of performance.

Phase 2: Formalise the technical contradictions

- 2e: Locate the problem causes

Linking the problems with the levels of the MSOP (our generic model of operational manufacturing systems) enables to locate the problems accurately. The resource or product directly appearing in the problem formulation are used to achieve this classification. The results are formalised as shown in Table 1.

Table 1. Results of problems processing

Function	Manufacture quality products		Satisfy a given Return on Investment		Manufacture various products	
Element of performance	Accuracy	Delay	Inflows	Outflows	Flexibility	Reactivity
Level4: Batch		Pb 3				Pb 6
Level3: Part			Pb 4			
Level2: Surface	Pb 1					
Level1: Material		Pb 2			Pb 5	

- 2f: Ensure the formulations

This step aims at removing all doubts, concerning the problem formulation. It must lead to a robust diagnosis of the manufacturing system. It is performed by interviews, and may change the classification of the problems. Three types of change are possible:

- Question the level of the problem. The third phase strongly depends on it. For example, we may ask if Pb1 (shown in Table 1) is really related to the couple 'surface – tool holder', or another one around it.

- Ensure that the element of performance diagnosed for a given problem can not be replaced by its contradictory. In this case, the problem remains in the same evolution contradiction. For example, concerning Pb1, is this problem really a problem of accuracy, or is the delay needed to obtain this accuracy too long.

- If the problem is linked to the financial contradiction, try to find its technical cause, by considering the other two contradictions. For example, concerning Pb4 (shown in Table 1), this problem may be questioned whether it can be linked to the quality of products, or the variety of products. In this case, a second classification is required. That's why a same problem can be classified in several cases in Table 1.

Phase 3: Identify a relevant subset

In order to save time during the design of the target architecture, a relevant subset (products and associated resources) of the manufacturing system has to be determined. We make the assumption that the architecture may be designed considering only the current sub-system where a majority of the problems occurs. PIA is then applied to this sub-system; this supposes that the designers will be able to propagate easily the technology evolution to the rest of the system later. To identify these products, the workgroup is interviewed, and the acknowledged contradictions are intensified.

- 3g: Select relevant products

The interviews of the the workgroup highlight products, which hold simultaneously several 'extreme' contradictions. They are found by intensifying the acknowledged problems. For example, concerning Pb1, treated in the previous 2e step: the analyst team requests the workgroup to select the products, which geometrical features are badly getting off their specifications, considering the rate of output (the variable of the system corresponding to delay) imposed to respect the delays.

- 3h: Restrict the relevant subset

Generally, following the g) step, a relevant subset emerges. If this selection is not obvious, prioritisation techniques, like cross-classification, may be helpful.

Phase 4: Design a target architecture

This phase aims at defining the target architecture corresponding to the relevant subset of the process.

- 4i: Restrict the architecture field of research

Let m be the number of contradictions involved in the problem handling process. Each of the $2.m$ elements of performance implied in these contradictions may take a maximal or minimal value. 2^{2m} theoretical specifications, corresponding to the 'extreme' architectures, can be performed, by combining the maximal and minimal values of the various elements of performance. The expert may classify these specifications, according to their relevance, in five groups:

- The potential specifications for which both elements of performance take bad values. As they are obviously not of any interest, they can be eliminated.

- The potential specifications for which both elements of performance of the same contradiction take good values. According to the principles of the contradictions, this state represent a major difficulty. Moreover, according to the current knowledge about the system, no technology may satisfy both of them. So, these specifications can be eliminated.

- The potential specifications for which both elements of performance complete each other. The current knowledge about the system make these specifications not of any interest. This may happen if the combination corresponds to the current situation, or if it does not suit the strategy of the company. Thus, they can be eliminated.

- The potential specifications for which both elements of performance complete each other, and may be relevant. The associated architectures are worth developing.

- The potential specifications for which the elements of performance of the same contradiction take good values, and for which a solution seeking direction exists, as, for example, an innovative technology. The associated architectures are worth developing.

- 4j: Ensure the specifications of the target architecture

The input data of this step is a restricted list of 'extreme' specifications. The Head team has now to ensure the specifications of the target system, according to the recommendations of the analyst and working teams. If several architectures are still remaining, they all must be developed. That means that the design process only goes on, if some lack of knowledge has been highlighted. Otherwise, the architecture can be assessed: the design process jumps to the 6s step, as shown in Figure 5.

- 4k: Design the architecture(s) of tests

Based on the remaining specifications, the target architectures must be studied technically and economically, for the relevant subset. So, the next steps only aim at filling the lack of knowledge previously identified. This design stage results in the specification of the potential architectures of a temporary system, dedicated to the tests. This system is, in general, different from the system which may be implemented, due to the constraints of tests !

- 4l: Select the architecture(s) of tests

The Head Team, advised by the workgroup, choses the architectures to develop, according to the strategy of the enterprise, and the cost evaluation of the tests.

- 4m: Develop the architecture(s)

During this step, the disciplines concerned with the design have to develop and realise all components (considering their spatial interconnections), and planify their temporal interactions. The architecture of the temporary system is used as an organisational model (a shared resource) allowing the coherence of all discipline work.

Physical and simulation tests, based on the relevant subset, enable to quantify the performances of the designed architecture(s). In the current state of PIA, the heart of the design process stops after this fourth step. The next two steps, shown in Figure 5, should help the managers (of products and resources) to complete the specification of the final architecture and check if the new technology can solve the problems and only cause very few new problems. If there are some, it may be useful to rewind to 3g step, and discuss the choice of the relevant subset.

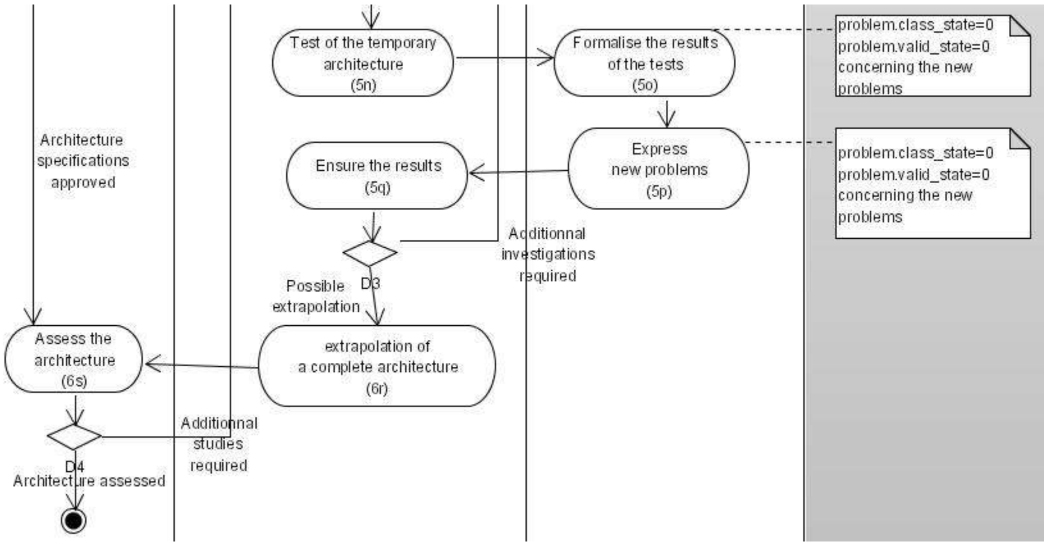

Figure 5. Last steps of the design process (UML Activity diagram)

The detailed design of the manufacturing system may now begin. The prerequisites are gathered. All the required information are specified. The final state shown on the activity diagram corresponds to the beginning of the 'classical' detailed design stage, managed as a concurrent design process, for example.

5 Study case

The support for this work is provided by SEW-USOCOME company, at their manufacturing plant in Haguenau (France, 67). This manufacturing plant is specialized in producing small and medium size electrical gear-motors (mass production). The shopfloor that produces housings of reduction-gear is now considering High Speed Machining (HSM). On the existing machining centers, fixtures had to be optimized in order to limit their distortion. Distortion of fixture was the main cause of problems on machined parts. In this context, HSM has been considered. First, we would like to clarify that the design method has not been created especially for Usocome, but applied and enriched during the entire project. As the collaboration has been going on for one year long, and is not still finished, the following description is focused on some relevant aspects. A first set of 20 initial problems have been expressed, within the workgroup, composed of technicians and managers of the shopfloor. The first two phases of PIA resulted in a review of 28 handled problems, located at the some of the four levels of MSOP. We will now detail the 3h and 4j phases.

To identify the relevant subset, the workgroup is asked which type of the produced parts is concerned by a majority of the 28 problems (problems of maintenance, lubrication, rejects...). We have let them chose between two approaches:

- A quantitative one: by taking each problem one after the other and associating to each a given part. This could define a set of parts.
- A qualitative one: by keeping a global view on all problems and identifying the part(s) from the common knowledge of the shopfloor.

The second way has been selected immediately, because of the evidence of the situation (according to the workgroup). A cast iron house casing ('HW30') had the approval of all the members (out of 400 different parts machined in the shopfloor). In fact, concerning this casing, all the reformulated problems are proven in side the corresponding sub system, excepted one out of 28, due to the maintenance of some old machines. So, solving the problems for this part is justified compared to the rest of the system. The objectives, resulting from the restricted field of research (4i step), can be stated as follows:

- Improve Accuracy of the product (9 problems out of 28);
- Maintain the Delay (only 1 problems out of 28);
- Improve Inflows of the system (5 problems out of 28);
- Do not take the Outflows into account (only 1 problem out of 28);
- Improve Flexibility (7 problems out of 28);
- Improve Reactivity (4 problems out of 28).

As we demonstrated it before, improving both Flexibility and Reactivity seems no to be realistic as they contradict each other. So, we discussed about the criticity of the related problems. According to the head team, other projects are already running in the shopfloor to improve the reactivity. Introducing High Speed Machining should not immediately look forward to improve the reactivity. The objectives were then set to: improve Accuracy, Inflows and Flexibility, maintain Delay and Outflows, and omit reactivity. To illustrate the link between these objectives and the development of the tests, very few financial models are applied during the development stage. Because of the non-problem of outflows, the most expensive configuration could be tested...

6 Conclusion

This paper introduces a design method leading from the definition of objectives to the detailed specifications of a complete manufacturing system. Based on engineering design principles, the method consists in processing the problems at a conceptual level. During early stages of engineering design, a shared resource is built on the cooperation of the members of a workgroup, composed of designers and users of the manufacturing system. Moreover the association of the problem processing and a process oriented generic model of manufacturing systems (MSOP) enables to support efficiently the assessment of new technology and processes to be implemented within a specific manufacturing system. It has been applied to numerous industrial shopfloors, among them SEW Usocome has been introduced in this paper. In this specific case, High Speed Machining has been related to the problems of the manufacturing and highlights its usefulness towards the performances of the system. Therefore, this new technology can be chosen by taking into account all aspects (technical and organizational) and not on a try and error manner which was previously applied in another shop floor the SEW Usocome Group. PIA results in a very fast and robust specification of manufacturing systems (through our applications).

In the context of engineering design, the efficiency of architecture specification has to be reinforced. As we applied the design method in shopfloors, the use of the architecture has been efficient to guarantee the coherence of the multidisciplinary project. It has now to be assessed for projects at a more global scale. Indeed, we presume that our design method provides more generic models to structure and integrate the knowledge about the system, for such projects. These concepts may be transposed to engineering design, to complete existing methods with product/process integration.

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GEISKOPF Francois
INSA de STRASBOURG / Mechanical Engineering laboratory
24, boulevard de la Victoire / 67084 STRASBOURG CEDEX / FRANCE
Tel: 00 33 3 88 14 47 00
Fax: 00 33 3 88 14 47 99
Mail: geiskopf@mail.insa-strasbourg.fr