SELECTING THE APPROPRIATE PROJECT MANAGEMENT PROCESS FOR R&D PROJECTS IN MICROELECTRONICS

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În acest articol discutăm alegerea procesului potrivit pentru managementul proiectelor de microelectronică. Pentru aceasta luăm în considerare diferitele tipuri de astfel de proiecte prezentate în literatură şi trecem în revistă câteva structuri cadru de astfel de procese. Acestea sunt dezvoltate pentru proiecte generale, iar noi le investigăm din punct de vedere al potrivirii pentru proiecte de microelectronică. Apoi le comparăm şi arătăm că niciunul nu este potrivit pentru toate tipurile de proiecte de microelectronică. În consecinţă, recomandăm abordări specifice pentru proiecte de dimensiuni diferite şi cu nivele diferite ale schimbărilor.

In this paper we discuss the selection of the appropriate project management process for microelectronics projects. For this we take into account different types of such projects, as defined in existing research and we review several existing frameworks and guidelines. These are created for the management of generic projects and we investigate them from the viewpoint of their suitability to microelectronics projects. Based on this review we compare them and show that none fits well every type of microelectronics projects. Consequently, we recommend the most suitable approach for different categories of projects, with different sizes and levels of changes.

Keywords: project management, project management processes, project success, microelectronics, innovation, change, complexity

1. Introduction

The success of an R&D project in general depends on multiple factors [1]-[6]. In order to complete such projects successfully, in a repeatable manner, the project team (or the organization that it belongs to) needs to have an approach that is defined and followed by the entire team, in other words it needs *a process* [7], [8]. A process is usually described as a set of pre-defined actions implemented in order to achieve a desired result [10].

Currently, there are several approaches for process frameworks that can be used in project management [10]-[12]. Some of them have been developed for

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generic projects, such as the PMI Body of Knowledge [10], while others have been originally developed for software projects, such as the CMMI [11] and the Agile Methods [12].

As demonstrated in [13], [14], high technology projects and specifically microelectronics projects have several distinguished features, which require special ability in selecting the most useful approach for their management. Most importantly, there is a large variety of microelectronics projects, ranging from very small to very large and from projects with few unknowns (and small degree of changes) to projects with a high degree of innovation and consequently many unknowns and high level of changes [13], [14].

In this paper, we review the main characteristics of the existing frameworks and their suitability for different types of microelectronic projects. We show that, if the selected approach does not match the characteristics of each type of projects, the projects may be inefficient or may even fail. We also give some recommendations for selecting the right approach for each type of projects.

2. Importance and challenges of selecting the right approach for a microelectronics project

Based on [7], [8], [10] and our experience with many engineering projects in microelectronics as well as in other high tech industries, we can say that selecting the right processes for a project is of critical importance. In this paper we analyze the project management processes, such as planning, monitoring and controlling, risk management, etc. Other processes, especially engineering (technical) processes are also used in projects, but they are out of the scope of this paper.

One dimension is the selection of project management process according with the project size, which may be categorized in small, medium and large [13], [14].

First, we consider the case of the projects with relatively low degree of change (deterministic projects).

If the project management processes are not well defined and not enough detailed for the complexity of that particular project, we will see delays in completing many project tasks for reasons such as lack of corrective actions, incapacity of assuring the completion of all the tasks needed before a new task is scheduled and incapacity to deal with risks. A suggestive example could be the design of a complex microprocessor without clear and detailed processes.

On the other hand, if these processes are too complicated, for a particular project they will be difficult to implement and will result in inefficient results. For example, having a too complex planning and monitoring and controlling procedures will result in a too long planning phase as well as long execution phase, due to many monitoring activities. In this case most probably the results will match the plan, but will be obtained with a higher effort and a longer time compared to the situation when the processes are correctly chosen. By analogy with the previous example, this case would be similar with applying the project management processes of a complex project (large microprocessor) to the design of a small operational amplifier.

The effects of different level of definition and detail of project management processes on the results of deterministic projects (i.e. projects with relatively low degree of change) are presented in Tab. 1. The three cases of processes are: process not enough defined/ detailed for the particular project, process rightly defined and detailed and process too heavy for the particular project.

As it can be seen, the only situation that leads to setting efficient goal and executing according to plan is when the project management process is rightly correlated with the size (or the complexity) of the project. In all other cases the results are inefficient, delayed and in some cases project failure is also possible. The highest probability of project failure is when the project management (PM) processes are not enough defined/ detailed.

Table 1

Effects of different amount of project management process definition and detail on project results. The case of deterministic projects

PM process not enough defined and detailed (too simplistic)	PM process rightly defined and detailed	PM process too complex
- Goals set incorrectly - Delays (tasks not planned correctly, unsolved dependencies) - Possible project failure (e.g. due to risks poorly managed)	- Goals set efficiently - Done as planned - Good quality	- Inefficiency (high effort for useless processes)

Another dimension, specific for high tech projects in general and microelectronics projects in particular, is the selection of the project management processes according to the degree of change in a particular project. As seen in [1], [13] and [14], high tech projects and microelectronics projects in particular can range from deterministic projects, with few unknown to projects with very high degree of unknown (and high level of change). These are the projects that are highly innovative, where a completely new architecture and technology are used and sometimes even a new functional principle is invented. When analyzing the main characteristic of different process frameworks, we specifically look at how suited they can be for projects with different levels of unknowns, and, consequently, different levels of change.

3. Existing frameworks and guidelines for project management processes

We analyze two different process frameworks: the PMI [10] and the CMMI [11] as well as a guideline, as provided by the Agile methods for project management [12].

3.1. PMI (Project Management Institute)

PMI stands for Project Management Institute, a not-for-profit organization established in Pennsylvania USA in 1969. Its most important contribution to the industrial community is its PMBOK Guide (A Guide to the Project Management Body of Knowledge), a "standard" document collecting a framework of recommendations for the project managers [10]. The Guide is structured within 9 Project Management Knowledge Areas (KAs) and 5 Project Management Process Groups, with a total of 44 processes that are to be applied during a project life cycle. The five Project Management Process Groups are:

- Initiating
- Planning
- Executing
- Closing
- Monitoring and controlling

Most processes are in the planning group (21) then in the Monitoring and Controlling (12). Their scheduling during project life, in terms of level of activity for the processes in each group is presented in Fig.1.

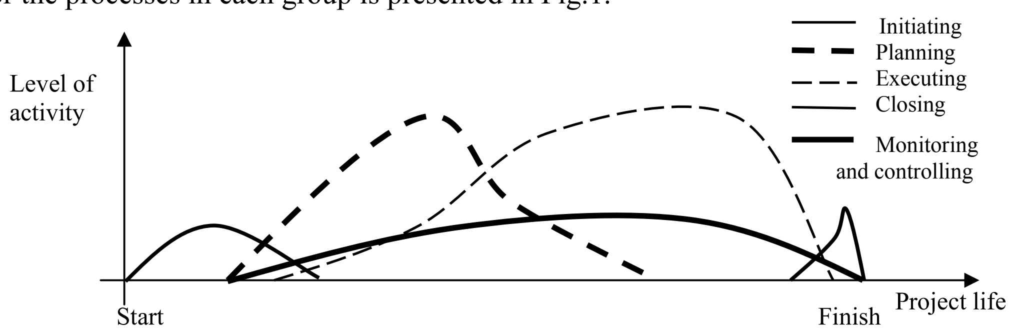

Fig.1. The variation in time of the level of activity in each Process Groups

The overlapping in Fig. 1 is mainly due to the fact that as the project evolves, some documents defined in the previous stages may need to be updated. As it can be easily understood, the monitoring and controlling processes take place during most of the project, starting with the planning phase and up to the final delivery.

Each process is defined at high-level, together with its inputs and outputs. A collection of “Tools and Techniques” that would facilitate the implementation of the process are listed, but no detailed specifications or recipes are offered for how to actually implement it [10].

We can determine the following main characteristics about the PMI approach:

- It is a general framework, arranging in a logical manner all the project management activities (called processes) that have to be considered at different moments of a project life-cycle
- It is scalable; each process can be applied in more or less detail/ more or less thoroughly depending on project size and characteristics. “It does not mean that the knowledge described (within PMBOK) should always be applied uniformly to all projects; the project management team is responsible for determining what is appropriate for any given project.” [10].
- It is particularly useful for large and complex projects, with a large project team, large number of stakeholders, large number of tasks done in parallel and many dependencies.
- Being rather general, a methodology and standard document templates as well as more detailed tools should be added.
- It is very useful for deterministic projects, where change is to be avoided and limited. Although this is not an explicit requirement in the PMBOK, we can easily reach this conclusion by its Integrated Change Control process. First of all, the essence of PMBOK is to determine a very good plan, with detailed definition of tasks and fixed schedules. A change could then occur for different reasons, such as a change in requirements, or a change due to an adverse factor. In principle, when a change needs to occur or has occurred, this process recommends reviewing it, approving or rejecting it, determining corrective actions so that its impact is limited and update all documents in the planning group, including the plan itself and the project scope document. This is excellent for a deterministic project such as building a bridge where a change could occur for example because of bad weather. In the case of innovative projects, where the technology has not been used before and clear requirements cannot be determined at the beginning of this project, the entire philosophy of the classical PMI approach is less useful. Indeed, for such projects, according to PMI, one should not start the execution phase because no detailed requirements are available and even if started, for each of the very numerous changes one has to redo the plan, the scope and the schedule. Such an approach is clearly futile in the case of projects with incomplete specifications and many changes, as there is the case in many microelectronics projects [1], [13], [14].

3.2. CMMI (Capability Maturity Models Integration)

Capability Maturity Models Integration (CMMI) has been developed by Software Engineering Institute (SEI) of Carnegie Mellon University, in Pittsburg, Pennsylvania. Historically they first introduced a CMM for software process (1995).

The SEI started from a different perspective than PMI, i.e. what an organization (software organization initially) should do to improve its results on projects or, otherwise said, its maturity. CMM defined and CMMI kept five levels of organization maturity, from Level 1 initial to Level 5 called optimizing:

- Level 1 initial – activities on projects are rather random, based on best intentions and efforts to complete projects. Projects cannot be completed in a predictable and repeatable way.
- Level 2 managed – projects follow a process that is introduced for each of them. The process is mostly reactive. Results become somehow predictable and repeatable.
- Level 3 defined – projects follow a process that exists throughout the organization. The process is proactive and results are generally predictable and repeatable.
- Level 4 quantitatively managed – process is now measured and controlled using a set of metrics. Results are predictable and repeatable.
- Level 5 optimizing – the process is continually improved, in a defined and controllable way, based on growing experience within the organization.

The CMM consists on several Process Areas (PAs), which are defined as a collection of activities or *best practices* to be performed for achieving a certain goal and can be viewed as a process framework.

The transition from software CMM to CMMI happened in 2002. The justification provided by SEI is that since the 90s, CMMs have been developed for "a myriad of disciplines" and "the use of multiple models has been problematic". Some of the most notable examples of disciplines include, according to SEI, systems engineering, software engineering, software acquisition, workforce management and development, and Integrated Product and Process Development. The CMM Integration project was formed to sort out the problem of using multiple CMMs. According to SEI "the CMMI Product Team's mission was to combine three source models—(1) Capability Maturity Model for Software (SW-CMM) v2.0 draft C, (2) Electronic Industries Alliance Interim Standard (EIA/IS) 731, and (3) Integrated Product Development Capability Maturity Model (IPD-CMM) v0.98—into a single improvement framework for use by organizations pursuing enterprise-wide process improvement".

According to SEI: "the purpose of CMM Integration is to provide guidance for improving your organization's processes and your ability to manage the development, acquisition, and maintenance of products or services."

Currently there are four "bodies of knowledge" (disciplines) integrated into CMMI model:

- Systems engineering
- Software engineering
- Integrated Product and Process Development
- Supplier sourcing

We can summarize CMMI main characteristics as follows:

- It is a general framework. Similarly with PMI's PMBOK, CMMI represents a framework of best practices to be followed during each project. Although the focus is on growing the organizational processes and maturity, we can look at these practices as useful for each project.
- It is scalable. Similarly with PMI, CMMI encourages tailoring of its recommendations according to the particular needs of each organization and project.
- Similar to PMI, for large projects it is particularly useful having a general framework that defines each activity (process) to be done at a certain moment of the project life and that also gives some guidance on how to perform it.
- Similar with PMI, CMMI describes *WHAT* to do and not *HOW* to do it – in other words provides a logical framework for the processes and gives guidance for what activities to be performed but it is each company's responsibility to develop the right processes accordingly.
- It is very useful for deterministic projects, but because it is very general it could be tailored to suit also projects with a higher degree of change. This is not necessarily a big advantage over PMI, but merely less of a limitation. It is mainly a reflection of its general character and hence still needs good processes to deal with change.
- A difference to PMI is that the PAs cover several categories, including Project Management (Planning, Monitoring and control, Risk management, Suppliers), but also Engineering (Requirements development, Requirements management, Technical Solution, Validation, Verification, Product Integration) or Process Management (Organizational Training, Organizational Process Definition, etc).

3.3. Agile Methods for Project Management

In the ever more competitive IT domain, a reaction against the bureaucratic, formal approaches that do not match the characteristics of modern IT projects has developed in the recent years. Therefore, Agile Project

Management methods have emerged, a category grouping several methods, such as Extreme Programming, SCRUM (iterative incremental process of software development), Feature Driven Development, and others [12], [15].

Their common principles were defined in the "Manifesto for Agile Software Development" [16] and can be described as trying to respond quickly to changes in the project by being less formal and having an iterative structure**.**

Clearly the main benefit of Agile methods is the ability to cope with change. The main ways for achieving this are the following:

- Iterative and Incremental Development. Agile methods break down the development of their new products into a number of repeating cycles called *iterations*.
- Progress Measured Via Completed Features. Rather than trying to track progress by measuring percent complete on intangible elements such as design, agile methods track progress by fully-completed and tested features.
- Short Iterations. By using short iterations, agile methods keep the feedback cycle short, allowing more responsiveness to change, and reducing the risk of building "the wrong thing" based on unclear or changing requirements.
- Open, Flexible Design. Designs are flexible and extensible using open standards wherever possible. Since the full set of requirements may be unclear at the beginning of the project, and will likely change anyway, prepare a flexible, extensible design that will allow you to add on features to support new requirements as they emerge.
- Empowered Teams. Teams of specialists who know their jobs well and have the experience (and maturity) to decide for themselves how to approach the problems at hand the best way.
- Personal Communications. Rather than focus on producing written documents to communicate design decisions, technical approaches, and other normally documented items, agile methods suggest that teams work in shared physical environments and speak face to face.
- Stakeholder (customer) involvement. The project has actively-involved stakeholders who work closely with the project team reviewing the work in progress, answering questions as they arise and providing immediate feedback.

We can summarize the Agile Methods main characteristics as follows:

- They are a set of principles and recommendations. Similarly with PMI's PMBOK and CMM(I), it represents a set of best practices to be followed during each project. However, it is less of a structured framework.
- They are scalable. Similar with PMI and CMMI, Agile Methods encourage tailoring its recommendations according to the particular needs of each organization and project.
- They are particularly useful for small projects, with a small project team, small number of stakeholders. If PMI and CMMI could be applied for projects of

any size, Agile Methods would handle with great difficulty large, complex projects with a large project team.

- Similar with PMI and CMMI, the Agile Methods provide a set of recommendations and give guidance for what activities to be performed. Here also we can say that it is each company's responsibility to develop the right processes accordingly – but here the processes are much simpler.
- It is very useful for un-deterministic projects with a high degree of change as opposed to PMI and CMMI. It is not useful at all for deterministic projects.

4. Comparison of existing approaches for ensuring project success

We compared the existing approaches for project management described above from the point of view of their usefulness in microelectronics projects. The main criteria that we used for this comparison are:

1. Their suitability for different types of project size and complexity. This is justified because, as mentioned, there is a great variety of microelectronics projects, from small size (in the range of 4-5 persons-months), to very large (in the range of 300-500 persons-months). We quantify their suitability with a fig. from 1-5, where 1 means completely unsuited and 5 means a perfect suit.
2. Their usefulness for different levels of project unknowns. As seen before there are microelectronics projects that are fully deterministic, with very few unknowns and few changes but also projects with a very high degree of innovation and consequently a very high degree of unknown and a very high number of changes. Again, we quantify their usefulness with a figure from 1-5, where 1 means completely useless and 5 means perfectly useful.
3. Their easiness to be understood and assimilated by a company and implemented in projects. Here 1 means very difficult to be understood, assimilated or implemented and 5 very easy.

We summarized the results in Tabel 2:

Table 2

Comparison of different project management process frameworks for different types of microelectronics projects

	Project size			Project degree of changes			Easiness of implementation	Total score
	Small	Medium	Large	Few	Some	Many		
PMI	3	4	5	5	3	1	4	25
CMMI	3	4	5	5	4	2	2	25
Agile	5	3	1	3	4	5	5	26

As it can be seen, all three are very similar in terms of total score. However, they are very different in terms of their suitability for different project sizes and usefulness for different degree of changes.

PMI and CMMI on one side are suitable for any project size (and perfectly fitted for large projects). Agile methods on the other side are suitable for small and somehow for medium size projects, but completely unsuited for large projects.

When it comes to the degree of change in the project, PMI and CMMI are useful for projects with few and some changes but not useful for projects with a high degree of changes – quite the opposite for the Agile methods. As seen in the above paragraphs, CMMI and especially PMI handle with difficulty the high degree of change. On the other hand Agile methods can be also used for projects with few changes but they are less efficient than PMI and CMMI.

Finally we consider that Agile methods are the easiest to implement, while PMI are also relatively easy. CMMI on the other hand is much more complex, because it covers not only PM processes, but also engineering, product management and organizational management. Trying to integrate all these into a unitary framework it has a very rich specific terminology and is the hardest to be understood – especially when it comes to the entire organization. On the PM processes it is thou very similar with PMI.

5. Recommendations for selecting the appropriate process framework for microelectronics projects

Based on the results of the comparison presented above, we can conclude that different approaches are best suited depending on the project size and project degree of changes.

For projects with few or some changes; a PMI approach is best considering the efficiency and the easiness to implement. Depending on the actual project size, we recommend a full PMI (with all the KAs) for medium and large projects and a reduced PMI set for small projects. Such a reduced set will include most of the processes, but in a reduced form, while others, such as: Procurement Management and Cost Management can be practically eliminated in small-scale microelectronics projects. It is possible to use CMMI for this type of projects, with similar results, but as seen above this is less straightforward and for organizations that are now introducing a PM process we recommend starting with PMI.

For projects with many changes the Agile methods are best suited. Thus, for small projects an Agile method can be directly used. For medium and large projects Agile methods alone are not enough and they have to be combined with PMI. A full description of how to achieve this combination will be analyzed in a future work. Basically, the project will be planned respecting the (short) iteration principle. The project main tasks will be approached in Agile manner, but their integration, monitoring and control and risk management will be performed in the PMI manner. Also, for these projects, a thoroughly defined communication process will have a huge impact on the success of the project [17].

These recommendations are summarized in Table 3:

Table 3

Recommendations for selecting the project management process frameworks for different types of microelectronics projects

Project size / Project no. of changes	Small projects	Medium - large projects
Few - some changes	Reduced PMI	Full PMI
Many changes	Agile	Combination of Agile and PMI

6. Conclusions

In this paper we analyzed different project management process frameworks and guidelines and compared them from the viewpoint of their suitability for microelectronics projects. We considered the main categories of such projects, based on their size and their degree of changes. The reviewed and compared project management approaches are the PMI, the CMMI and the Agile methods.

Selection of the appropriate approach for a particular project is of primary importance, as it can determine the project success in terms of efficiency and quality or even its completion [7] – [9].

If we select a well-defined PMI-based process for a project with many changes the result will be a very inefficient project due for instance to the high effort spent to detail the requirements and the plan, effort that will have to be restarted over and over again due to the numerous changes. In fact, the changes will probably be so many that they will overwhelm these efforts.

Similarly, if we employ Agile methods alone to a large project with many changes, the project may not even complete, due to the inability of these methods to cope with large size, high complexity projects.

We concluded that for projects with few or some changes, such as projects introducing few new features to existing integrated circuits, the PMI approach is the best suited. Depending on the actual project size, it can be a full or reduced PMI. For small projects with many changes an Agile method can be directly used, while for medium and large projects with many changes a combination of Agile and PMI methods is best suited.

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