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# Modern Project Management Approaches in Uncertainty Environments: A Comparative Study Based on Action Research

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**Abstract:** Change and high uncertainty levels are the main characteristics of current project contexts. Years ago, the traditional project management faced problems when operating in these environments. Thus, at the end of the 20th century, new project management approaches were conceived to provide a more effective answer to such contexts. These methods propose a different approach, aimed at promoting the project flow by focusing on the short term. However, their adoption involves certain adjustments from a managerial perspective. The influence on the way resources are used is of special interest, as it may cause unexpected behaviors and reactions. The literature vastly analyzes the features and benefits of these methods. Nevertheless, there is a lack of empirical evidence about both the practical implications of the transition process toward them and their superior performance. Thus, this research aims to contribute to filling this gap by providing real-world based evidence related to the change process from a traditional project management approach to a flow-driven one. With this objective in mind, we analyzed the transition processes experienced by two design departments from companies of different industries. The results of the study confirm that the adoption of this type of approach can improve an organization's performance and simplify its project management system. Therefore, we consider that our findings are useful for anybody interested in these methodologies. From the academic perspective, the evidence obtained in this study contributes to supporting the research works suggested by the literature. Furthermore, it can be helpful to guide further research and extend current knowledge. Additionally, they can assist companies in the improvement of their current project management approaches.

**Keywords:** project management; progressive elaboration; critical chain; agile

## 1. Introduction

A project is an activity to which risk and uncertainty are inherent [1]. High levels of competition in the current global context add even more complexity and uncertainty to project management (PM) [2,3]. In this context, managing uncertainty is essential in order to be competitive. The literature on the subject reflects this fact, linking a competitive position with the ability to generate and maintain differential factors, such as reliable on-time delivery or high service levels [4–6]. These factors are related to proper time management, which can be understood as a reduction in lead-time or cycle time. In these circumstances, traditional PM approaches have often been unable to respond to the demands of the current context [7]. An example of this is the demand of various organizations for methods with a greater orientation toward execution as a way to ensure a proper response [8]. Orientation toward execution is one of the main features of critical chain project management (CCPM), which has evolved over time to improve its capabilities. Indeed, according to a recent study of Ghaffari and Emsley [9], "CCPM has been on a long journey since 1997, from studies on introduction of the new method, evaluating it and finally improving its techniques" (p. 51).

Along this same line is the significant increase in PM approaches, methods, and tools, which has given rise to the wide range of PM options available today. Some of the maximum exponents of this are the agile method [10] or the CCPM method mentioned above [11]. Beyond their differences and nuances, these methods share a clear orientation to managing the execution of projects by focusing on the short term. The "Agile Manifesto" [10] summarizes the aim and the general approach of the agile philosophy—simplicity and adaptability to change being two of its main features. For its part, CCPM is rooted in the theory of constraints [12]. It has proven to be effective when dealing with uncertainty in both single and multiproject environments [1,13].

Since their appearance, these methods have continued to evolve, both conceptually and as a result of the possibilities that technology offers. Consequently, new needs arose, which in turn led to the development of specialized software. This, together with the abovementioned evolution of PM methods, enhanced their overall performance [9,14–16]. Thus, the potential of methods developed from the consistent integration of complementary components has been reported in the literature [14,17]. Nevertheless, the amount of works concerned with this issue is scarce.

Finally, the maturity level of the company is another important issue concerning the adoption of a suitable PM approach. As already mentioned, there is a wide range of PM approaches currently available. However, certain aspects, such as experience or qualification within the organization, also determine the limitations of the organization [18,19]. Therefore, these aspects must be considered when addressing the implementation of a PM methodology [7].

The authors of this work have a combined experience of over three decades in CCPM implementation and related research projects. Throughout this period, we witnessed the evolution of the method. In this sense, the contribution of this article is that it responds to the additional research suggestions of other authors on the subject, which exposes the evolution of the method over time, identifying further research areas [9,20]. The present inquiry deals with some of these issues, such as application to the development of new products, the additional techniques applied ("full kitting" and Kanban), or aspects related to the empirical testing of the method improvements. Furthermore, this work is not limited to their use concerning CCPM but deals with the expansion of these improvements to approaches other than CCPM. As a result, we present the results of two real experiences concerning the management of design phases using evolved approaches. In this sense, projects entailing design tasks (e.g., new product development or improvement of existing products) are of special interest. The reasons for this are diverse. On one hand, they are often carried out on innovative or unknown topics. Furthermore, intermediate results often lead to unexpected outcomes, requiring decisions to be made on the fly. On the other hand, the design stages typically occur at the beginning of the project life cycle. Consequently, the delays generated here are directly transmitted downstream, causing penalties, extra costs, and more pressure, among other things. Therefore, the results of this study may be of interest to academics and practitioners alike.

## 2. CCPM and the Agile Approach

### *2.1. The Theory of Constraints (TOCs) and CCPM*

CCPM is part of the theory of constraints, developed by Goldratt [12]. The main idea behind TOC is that the capacity of a system is determined by a few points, known as limitations. Consequently, the management of these points acquires special relevance when managing a system (usually an organization).

The TOC was originally developed in the field of production, giving rise to the Drum Buffer Rope approach (also called DBR) and the five steps of the so-called "Process Of OnGoing Improvement"

(POOGI) [12]. As the theory developed, its principles were expanded to other areas such as distribution, marketing, or projects, among others. Thus, in 1997 a new approach was presented through the publication of the book Critical Chain [11]. CCPM is, therefore, the adaption of the TOC principles to project contexts, which are typically characterized by high levels of uncertainty.

According to some authors, CCPM is the most important innovation in project management since CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) [9,21]. One of the main characteristics of CCPM is its orientation toward on-time delivery. As in DBR, workflow improvement is promoted to achieve this purpose. Thus, time management is the central aspect of this approach, based on the belief that it will have a positive impact on scope and budget management [20].

CCPM also considers the impact of human behavior, which according to this perspective has an amplifying effect on uncertainty, thereby negatively affecting projects [21–23]. The negative impact of human behavior on projects as defined in CCPM is summarized as follows [24]: "bad multitasking", "student syndrome", and "Parkinson's law". Bad multitasking is defined as switching between tasks, causing delays on all of them. Student syndrome is the trend to start and carry out tasks late, forced by the pressure generated by delays or urgency. Finally, "Parkinson's law" was defined by its author as follows: "work expands so as to fill the time available for its completion" [25].

Based on the systemic perspective of the TOC, CCPM proposes a general solution for project management, including single and multiproject management. As in other TOC-specific approaches, buffers are a fundamental component of the proposed solution. They provide protection against uncertainty and serve as a performance monitoring mechanism. A number of authors have suggested some steps to summarize this approach [26–28]. In order to facilitate understanding, the main aspects addressed by CCPM are summarized below: single-project planning, execution management, and multiproject planning.

1. Single-project planning: the starting point is a project schedule as in traditional PM [11,22,23]. Then, the "critical chain" is identified: the longest sequence of tasks after the elimination of potential resource conflicts. CCPM extracts certain time from the activities and concentrates a part of the extracted time at the end of the critical chain, thereby creating the "project buffer". It aims to both protect the project deadline and provide valuable information for project execution. Finally, the critical chain is protected from delays in noncritical activities by inserting "feeding buffers".
2. Execution management: the general approach is to manage the entire system based on the management of buffers (project buffers in particular). Buffers do not only protect deadlines against uncertainty. Based on the progress reports, they also make available valuable information about the current situation. Thus, the managers receive early warnings and react, and make decisions where required.
3. Multiproject planning: firstly, the project schedules are scheduled based on the single-project planning approach [29]. Then, these schedules are staggered according to overall priorities and available capacity. The staggering mechanism is another type of buffer, called scheduling buffer or capacity buffer [22,23,30,31].

Since its inception, CCPM has undergone an evolutionary process until reaching its current state of maturity [9,20]. Rojas Luiz et al. propose a state of the art evolutionary model in CCPM composed of three stages: conceptual, deepening of applications, and methodological maturity. The conceptual stage (2000 to 2005) is mainly concerned with the foundations of CCPM and critical analysis. The intermediate stage (i.e., deepening of applications, 2006 to 2010) includes works related to both in-depth analysis of specific aspects of CCPM and empirical studies developed in diverse industries and sectors. Finally, the methodological maturity stage is dated to 2011. Since then, CCPM has been expanded to multiproject contexts, combining with other approaches.

One of the aspects related to the evolution of the method is full kitting. Full kitting is a concept imported from other contexts different than PM [32]. Ronen introduced this concept under the name "complete kit" [33]. According to this idea, working with incomplete kits carries negative consequences, referred to as "the evils of an incomplete kit". It is defined as "the preparations that are required or recommended to be performed before executing a set of tasks" [17]. Today, it is considered to be a part of the CCPM approach, but it remains to be uncovered by the PM literature [20].

Based on the amount and variety of scientific production related to this topic, it is concluded that the current level of maturity of the method is due to the evolutionary process undergone. As a result, diverse aspects requiring further investigation have been identified. For instance, Ghaffari and Emsley reported some potential research areas related to CCPM, which are recommended as a major contribution [9]. Similarly, Rojas Luiz et al. suggest further research areas based on recent topics of interest related to CCPM [20]. Interestingly, both works agree on the need for additional empirical research. Rojas Luiz et al. [20] emphasize the lack of real-world based results, claiming empirically tested results that support the superior performance of improved methods.

### *2.2. The Agile PM Approach and Kanban*

The abovementioned "Agile Manifesto" [10] gathers the values of the agile PM approach, summarized in twelve underlying principles, which guide the agile practitioners. It was the result of a meeting of experts linked to software development. Years before, they had already identified the need for a different project management approach. This need gave rise to the development and evolution of various alternative methods to traditional management in the last decade of the 20th century, such as Extreme Programming (XP), SCRUM, Dynamic Systems Development Method (DSDM), Adaptive Software Development, Crystal, Feature-Driven Development, etc. [34].

Interestingly, many concepts today characteristic of this context, such as iterative and incremental software development methods, or adaptive software development, are were established several years before [35,36]. Thus, Abbas, Gravell, and Wills establish the origins of agile methods toward the middle of the 20th century, recounting the evolutionary process that has occurred since then [37].

Each agile method has specific characteristics. Therefore, when adopting an agile method, it is important to consider the characteristics of a method, as they determine its suitability for the type of project to be carried out. Furthermore, depending on their characteristics, each method is more prescriptive or adaptative (i.e., roles, artefacts, etc.) [38], thereby determining its level of ease of application.For example, Kanban is one of the least prescriptive methods, its main characteristics being continuous flow of work and work in process (WIP) control [34], [38]. Scrum is more prescriptive: roles, timeboxed iterations, meetings, and artefacts, which are not required in Kanban. XP is even more prescriptive. Nevertheless, the agile methods are less prescriptive than traditional methods and share the need for flexibility and adaption to changing needs.

The origin of the application of Kanban to projects is founded in the field of software development, in line with the abovementioned problems related to agile methods. The original Kanban was created as part of the Toyota Production System developed by Ohno [39]. This was the main source of inspiration for the application of Kanban to software development, and later to project management [22,40]. However, the Kanban approach for project management is also rooted in the TOC. Thus, the works carried out by the promoters of the Kanban approach for project management explain that it also has some characteristics of the TOC [41,42].

The result of the evolutionary development process of Kanban has been reflected in various documents over time [40,43], where the values, principles and practices on which it is based are collected. The principles of Kanban are: visualize work; limit work in progress; manage flow; make process policies explicit; implement feedback loops; improve collaboratively; evolve experimentally. According to the authors, the adoption of Kanban allows one to obtain significantly improved and lasting results. Furthermore, to start working with Kanban companies must not make significant changes in their current working procedures.

Another aspect of interest for this study is the relationship between Kanban and TOC-CCPM. Leach [22] states that Kanban solves two important common problems related to project management: the reduction in multitasking at the individual level, and the management of those resources assigned to both project and non-project activities. He considers this to be a significant contribution to PM. Furthermore, Leach states that Kanban can be a good starting point for those organizations initiating the change of their project management model. The main reasons for such a conclusion are various. On the one hand, Kanban allows for the reduction in the levels of multitasking and WIP with ease. On the other hand, the trade-offs it entails are very low. Consequently, it recommends the adoption of Kanban as part of the process for CCPM implementation projects.

In brief, despite being considered an agile method, Kanban has been developed somewhat later than most other methods. It has also been inspired by other philosophies such as Lean and TOC. Additionally, its development has taken place in the professional sphere. Consequently, the literature is very limited.

## 3. Objectives and Research Methodology

The objective of this study is to deepen knowledge and provide empirical evidence of PM methods based on current trends; it aims both to provide an answer to a real-world problem and to generate new knowledge [44]. Its purpose is therefore both exploratory and descriptive [45]. The study has an empirical background that includes observations from both academicians and practitioners [46–48]. Thus, an action research approach [49], a variant of case study research, has been applied. This approach is often used in operations management research [50], and requires the investigator to be actively engaged in the activities being researched, thereby influencing decisions and results [50–54]. The approach used in this study is based on Coughlan and Coghlan [54], as explained in Figure 1.

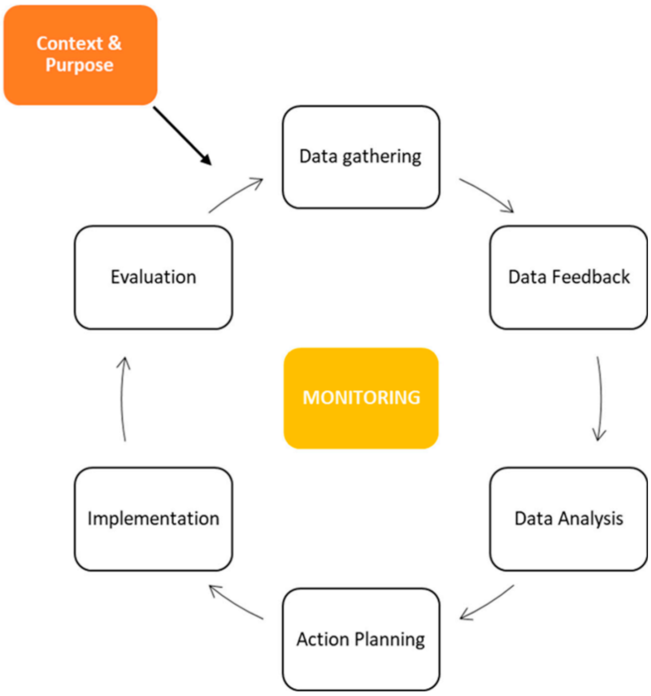



**Figure 1.** The Action Research cycle [54].

- Context and purpose: this preliminary step deals with the underlying logic of the research, addressing aspects such as its interest, the suitability of the approach, and the expected contribution or outcomes.
- Data gathering: the researcher is directly involved as a participant; through participant observation, he/she can directly access data and information as they are being generated.
- Data feedback: before proceeding with further analysis, the researcher provides the case company the data gathered.

- Data analysis: the researcher and the practitioners involved in the case study analyze the data together. This allows for the proper combination of both the in-depth knowledge of the company and the theoretical know-how of the researchers. Such a twofold perspective is essential to ensure that the outcome of the analysis is suitable for the case.
- Action planning: the outcome of the analysis to be implemented requires resources and support from the company. Furthermore, aspects such as the scope and the timing of the action, or resistance to change, must be considered. Thus, the parties must analyze and decide when and how the action will be carried out.
- Implementation: the company is responsible for the proper implementation of the action as defined in the plan.
- Evaluation: it is a review of the cycle already carried out. The aim of this step is to learn from experience and receive feedback, which will be used as an input for the next cycle.
- Monitoring: this is a meta-step. Monitoring is a continuous activity applied to all the steps through all the cycles. It provides essential information to know what and how is happening along the entire process.

Research for this study is based on work carried out in two companies located in the Basque Country. While these companies operate in different industries, characterized by high levels of uncertainty, activities on which the case studies are based took place within time frames that are partially concurrent. The observation period for both cases was one year: from May 2018 to April 2019 in Case 1, and from January 2019 to December 2019 in Case 2. It is important to note that the approach used and experience gained in Case 1 formed the basis of the approach for Case 2.

## 4. Case Studies

This section deals with the case studies that comprise the present study, and the presentation of each study follows the same structure. First, the context of the company is introduced, followed by a description of both the method by which fieldwork was carried out, and the specific context in which it was applied. Finally, an analysis of the fieldwork and the results of the case study are presented. Particular attention is given to the method applied and to its adaptation to the context of each company.

### *4.1. Case 1*

The first case study was carried out in a company devoted to the manufacture of machines and tools. It owns five centers and is part of joint ventures in three continents, and employs over 350 individuals. The company is mainly oriented toward the automotive, power generation, and aeronautics industries.

This study was concerned with the company's machinery business unit, which operates in an engineer to order (ETO) context. In particular, the study focused on design work performed by the company's engineering department, which is composed of 20 professionals skilled in the context of mechanical-electrical design and commissioning-activities. While these resources are highly versatile, they also subcontract certain activities to external professionals.

The department's design activity is mainly associated with new product development (NPD). Starting from a standard base, these projects aim to supply tailored products to final customers, a process that typically takes around 6 months. While viewed from a high-level perspective, these projects follow a repetitive pattern, and tailoring requirements also turns them into projects for the production of specific products. The environment is also characterized by high levels of uncertainty and competitiveness. Moreover, adherence to agreed-upon delivery dates is essential, and significant penalties are incurred if delayed.

As a result of its success in recent years, the company's machinery business unit was forced to expand its resources. This new situation revealed the PM approach at the time to be insufficient, requiring an overall enhancement to meet the increased needs of the company. Consequently, in 2018 the company launched an initiative to implement a new methodology whose central component was CCPM. However, the traditional version of the CCPM method was enhanced by the following complementary elements:

- A suitable project life cycle [7] as the basis for integrating those elements that compose a methodology that is consistently aligned with the project strategy;
- Decoupling points inserted between phases in order to stop or slow down the spread of delays and variability occurring in previous phases. The aim of these points is to avoid blocking project flow [55];
- Full kit (FK), in which a project team has everything it needs to carry out a task before starting it; a date by which the FK is to be completed; a list of items required for completion of the FK [17]. This proactive focus on preparation has a twofold effect on project performance: it contributes to reducing the impact of uncertainty, and enables smoother project execution as a result;
- Kanban, which is an emerging practice framed in "on-demand" scheduling [7]. This control of work in process (WIP) is the key to maximizing throughput. By maintaining low levels of WIP, project flow is enhanced, thereby resulting in cycle time reduction, optimization of resources, and improved profit, among other things.

The new enhanced CCPM methodology was applied to the entire business unit, covering both single and multiproject levels. However, given the scope of this study, the focus is on the management of design activities. The main features of the enhanced approach (see Figure 2a,b) are described below.

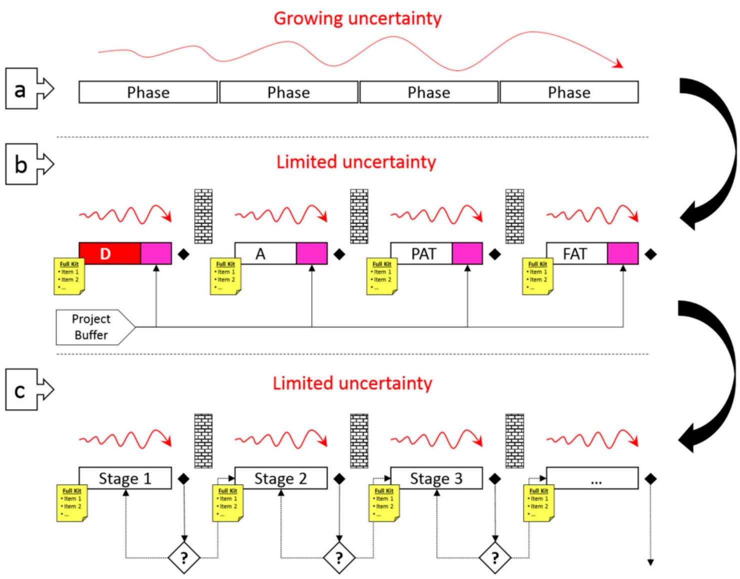



**Figure 2.** Project management approaches. (**a**): Generic sequential multi-stage project life cycle; (**b**): Sequential multi-stage project life cycle for case 1; (**c**): Generic sequential multi-stage project life cycle for case 2.

Four stages make up the generic project life cycle: design, assembly, Preliminary Acceptance Test (PAT), and Final Acceptance Test (FAT). These stages must be mutually consistent, and respect deadlines and capacity limitations. Thus, each stage is planned as an individual project, according to the improved CCPM approach. The overall PM system was modelled as a combination of subsystems, managed consistently with overall priorities by the system planner (i.e., the master scheduler). In short, for each stage, this involves decoupling points between projects, Kanban-oriented task decomposition on two levels, aggressive task duration estimates, and insertion of FKs and checklists. There are, however, significant differences between the stages that require them to be addressed differently.

Each of the PAT and FAT phases lasts approximately one week. The former is carried out together with the customer on company premises, while the latter is carried out at the customer's facilities. Although dates are agreed upon with the customer, both phases often suffer delays as a result of customer requests. Consequently, monitoring dates and resource loads becomes essential to the scheduling and rescheduling of phases on feasible dates.

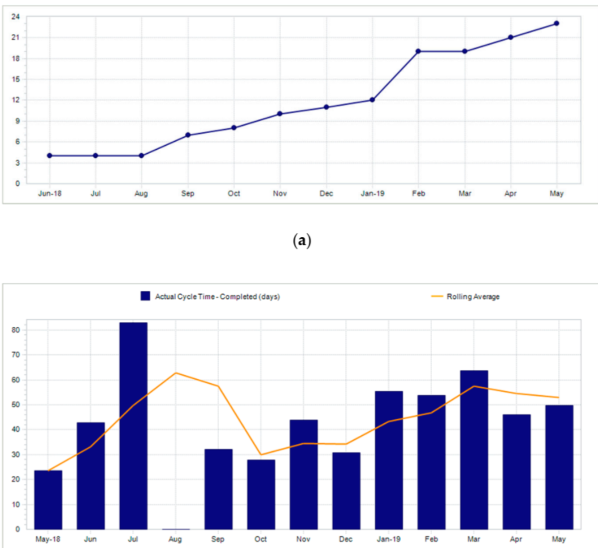
The design and assembly phases, on the other hand, are managed as systems governed by their respective bottlenecks or drums, in accordance with the principles of the theory of constraints (TOC-CCPM). Their respective drums (i.e., the mechanical and/or electrical designers in the design phase) govern each subsystem according to the priorities and the WIP levels set for each subsystem. In the case of the design stage, the WIP was limited to three concurrent projects, in order to produce suitable results in terms of throughput and resource usage.

Results

The new enhanced CCPM approach changed certain managerial policies and working habits. Results were consistent with expectations and the relevant literature. The first result observed was a significant reduction in the impact of uncertainty when compared to the original scenario. On one hand, the use of FKs urged on-time fulfilment of conditions required to launch phases properly. FK monitoring was also helpful for visualizing the situation in a timely manner, allowing for early detection of potential problems or delays. On the other hand, the combination of the project life cycle and decoupling also proved to be effective in reducing uncertainty. The decoupling points, properly positioned, protected deadlines against delays occurring at early stages.

As a result of the new approach, certain valuable outcomes were also reported concerning project planning and execution. First, suitable WIP limitation allowed for resource concentration in less concurrent projects and activities. Thus, project plans became shorter, while multiproject planning became easier. Multiproject planning was then applied to each subsystem, enabling individual phases to comply with their diverse limitations more easily. In this way, the corresponding drums set the WIP limits for both subsystems, subordinating their respective priorities to overall priorities.

The application of the new method also produced interesting results from a quantitative perspective. Notable among these are a throughput increase and cycle time reduction (see Figure 3). Additionally, with the new approach, required design hours decreased by between 5 and 10% on average, depending on the machine type. Likewise, use of the new method over the defined period was instructive for the organization. Management skills developed by the staff throughout this period indicate that the organization currently has a higher level of maturity compared to its level at the beginning of the initiative.




(a)

(b)

**Figure 3.** Throughput and cycle time (Case 1). (**a**): throughput (cumulative number of completed designs, monthly); (**b**): cycle time, actual (monthly) and average.

*4.2. Case 2*

Case 2 was developed in a company dedicated to the design and manufacture of parts for the construction industry. The company exports material to more than 50 countries around the world. It is therefore key for the company to provide solutions specific to the characteristics of each context. Its main facilities are in the Basque Country, and its 2000+ professionals are distributed throughout its various branches and subsidiaries.

This study is limited to high-priority projects in the research and development (R&D) area. R&D is a part of the company's technical department and encompasses design and application activities of four product teams. Team managers are responsible for the development and maintenance of a family of specific products and solutions. For this purpose, they "own" the team resources (mainly engineers and draftsmen/women) required to develop new products and to improve the existing ones. Thus, the skills and knowledge of each team are specialized, which hinders both versatility and resource sharing.

The company's existing approach to PM consisted mainly of a set of monthly meetings, worksheets, and templates. The meetings follow an information cycle that starts with the individual assessment of project progress in each team. The technical department manager and the team managers analyze this information in a multiteam R&D meeting. Then, the technical department manager reports the results and conclusions of this meeting in a separate product management meeting. This meeting governs the issues related to new products, and gathers implicated managers. It is important to note that due to the limitations of PM staff, this approach is only applied to strategic high-priority projects, which are identified by the product management team on an annual basis.

R&D teams mainly work with projects, but they also provide support to other sections of the company (e.g., technical support and supervision). Nevertheless, their maturity level is low in general in terms of PM (e.g., it is a young staff with a technical background that lacks experience and PM training). Only the team managers, who are more experienced professionals, received some PM training.

The manager of the technical department reported that the main problem related to projects were delays. Despite past efforts, projects in general were delayed. Limitations in PM maturity level were, from their perspective, the main cause of this problem. Thus, they decided to launch a project to improve the PM system and its performance.

Strategic projects are essential investments for the future. These projects aim to develop and make available those products considered strategic as soon as possible, but do not have final customers or real need dates. Instead, they involve diverse internal stakeholders with different perspectives in need of reconciliation. Therefore, deadlines are defined according to overall priorities and the situation.

In the most general cases, the life cycle of these projects ranges from product definition to on-site testing. Similar to Case 1, the entire process involves going through design and development, manufacturing, and testing. However, not all project stages are always carried out. Additionally, certain variables, such as availability of building works allowing the performance of tests, have a significant influence on project deadlines. Hence, depending on the characteristics of both the product and the development process, the duration of the total cycle typically ranges between one and two years. Once it has completed its life cycle, a product is ready for manufacturing.

Notwithstanding the specific characteristics of Case 2 and the particularities of its projects, similarities with Case 1 in terms of design activities were identified. Thus, the new CCPM approach applied to Case 1 seemed to be suitable for Case 2. Consequently, the research team carried out a comparative analysis of the contexts of both companies to confirm whether the method was suitable or not.

Projects constitute the main object of study in both contexts. This means that these are contexts with significant levels of uncertainty, and that resources are devoted almost exclusively to carrying out projects. Likewise, the resources have a marked technical profile, and at the same time, low levels of maturity and training concerning PM. However, there are also important differences between the two cases, such as the characteristics of each organization and their respective sectors, as explained above.

After analyzing the similarities and differences between both contexts, it was concluded that the new CCPM approach of Case 1 could work properly in Case 2. Nevertheless, these findings prevented us from applying the methodology associated with Case 1 directly to Case 2. Instead, an adaptation of the methodology to the context, with special attention given to the specific features of each project, was necessary.

#### 4.2.1. Adaptation of the Methodology to Case 2

The solution sought for Case 2 aimed to take advantage of the main benefits reported in Case 1. The main challenge was to overcome the lack of maturity of Case 2 concerning PM, and particularly the inexistence of an established and specific method (which, in Case 1, was CCPM). In other words, apart from being efficient, the approach had to be easy to implement. Thus, before adapting the approach to Case 2, the following aspects specific to Case 2 were taken into consideration:

- As each product is unique, projects are nonrepetitive. This means that only certain concepts can be standardized for re-use, (e.g., templates and procedures). Furthermore, in general, this option is restricted to high-level and generic perspectives;
- Project life cycles are composed of sequential phases connected by gates. These gates are decision points, which act as go/no-go mechanisms. Occasionally, however, certain phases can be concurrent to the main sequential structure of the project life cycle. They are also linked to the gates of the main phases;
- Once a gate is reached, there is real chance that the phase will have to be partially or completely repeated. The main causes identified for such a result are deficient definition of objectives, lack of project strategy, and insufficient involvement of key stakeholders;
- Early delays have a high impact on deadline compliance (i.e., delays are easily transferred downstream).

The solution designed for Case 2 is shown in Figure 2c. Decoupling and FKs (i.e., the main components to dealing with uncertainty) are maintained. Furthermore, the approach encourages maintaining low WIP rates, and resources are concentrated in less concurrent tasks. The main differences between this approach and that of Case 1 concern the basic PM approach and use of the FK. As explained above, the basis for the PM approach in Case 1 was CCPM. By contrast, in the context of Case 2, there was no existing formal PM approach. However, given the small sizes of the teams, the four team contexts were not complex to manage. Thus, a simple approach oriented toward compliance of priorities and maintaining low WIP rates was designed. In addition, an easy tool providing support to the abovementioned approach was created. This tool is a spreadsheet focused particularly on managing the FKs and information related to project progress. Finally, the staff were trained to manage both the tool and the key concepts of the new approach.

Of further note is the use of the FK in the context of Case 2. Participants were encouraged to reflect further on the causes of high probability of failure. After analyzing the causes and looking for possible solutions, it was concluded that the inclusion of key stakeholders from the beginning would substantially improve the probability of success. Consequently, it was determined that stakeholders be included in the FK, making them co-responsible for the definition of objectives and of acceptance criteria.

#### 4.2.2. Results

After a 10-month period working with the new method, a series of interviews were carried out with the manager, the team leaders, and various team members of Case 2 to assess the results of work carried out. They all gave the method a positive evaluation, acknowledging that it was helpful in structuring and planning projects. They also highlighted the positive effect of combining WIP reduction, prioritization of activities, and the concentration of resources, all of which facilitated the management of resources, increased project speed, and improved productivity. Team managers also agreed that decoupling had been helpful in absorbing the effect of uncertainty. As a result, virtually all subprojects were progressing either as planned or better than anticipated. Therefore, despite admitting that the new method required more dedication, managers agreed that it could be considered as a valuable investment.

In addition, the use of the FK revealed previously hidden issues, such as the difficulty of integrating main stakeholders in the development of the FK itself. This reality did not surprise the participants but allowed for a more objective calibration of its impact on the result. It was also evident that the FK encourages many problems to be identified earlier. However, this contrasts with the perspective of the team members, who gave less value than the managers did to the FK.

Team leaders made some other evaluations based on their personal experiences throughout the study period. This allowed for an in-depth analysis, as well as an identification of problems and opportunities for improvement. Main contributions are summarized below:

- All participants agreed that the weekly perspective was clear, manageable, and sufficient for its context. A more detailed level of information was not necessary;
- One of the teams went further than the others. The team implemented a weekly dynamic of shared follow-up that was of great help to them in terms of management;
- The team managers determined that team members were not yet qualified to manage projects themselves. Furthermore, the manager of the technical department and one team manager considered this an opportunity. They believed that if the team took on the management of projects, their involvement in achieving objectives would increase. Moreover, the team managers would free themselves of part of their existing responsibilities. This would allow them to focus on other issues considered crucial for the company;
- The main criticism concerned the limitations of the tool. The team managers agreed that the limitations of the tool made it difficult to manage and communicate information.

Finally, observation allowed researchers to identify other notable outcomes. Despite having been trained, team leaders required additional support to plan projects according to the new approach. Consequently, the tendency to plan in excessive detail was observed repeatedly. On the other hand, the organization's criteria for setting objectives influenced the way the projects were planned. In this way, milestone setting and project decomposition were carried out based on such criteria, sometimes resulting in misalignments regarding the strategy of the project.

## 5. Discussion and Conclusions

### 5.1. Discussion

Although every project is supposed to follow a strategy, the level of definition with which the projects were previously launched was certainly significantly lower than required. On one hand, a high-level perspective or overview of the whole project required. Each phase must also be deployed at the operational level. This second level serves as the basis for short-term (i.e., execution) management. Apart from providing a clear perspective of the project situation, the second level is also easy to update and interpret. The new method forced the development of a project strategy at these two levels, consistent with each other. Interestingly, this approach proved to be suitable to Cases 1 and 2, both of which required a twofold perspective (i.e., an overall, long-term view and a detailed, short-term view).

On the other hand, the coherence between both levels implies that, when dividing the project into phases, there must be a logic based on the dependency between phases. Consequently, it is also necessary to determine the conditions for proper phase opening and closure. In other words, decomposition must be carried out with a global perspective, aimed at facilitating the progress of the project.

The combination of the decoupling strategy based on phase decomposition, together with the FK concept, proved to be effective in dealing with uncertainty. The FK played a crucial role for this purpose. In Case 1, the FK was not only helpful in tracking the progress of preparation tasks, thereby ensuring that phases were ready to be launched on time, it also served as a proactive tool. The need to define the conditions required the launching of phases in advance and according to the project strategy impelled analysis of project requirements. It also necessitates decision-making sooner than in the past, which proved to have a preventive effect. Furthermore, faster decision-making enhanced the impact of such decisions. For example, in Case 1, the requirements for launching stage 2 (assembly) of the project led to a division of supplies into two categories: critical and noncritical. As a result, the launch of stage 2 was conditional on the fulfilment of both FKs, thereby influencing the design stage. Similarly, in Case 2, key stakeholders were integrated from the start of the project. This led to a definition of the conditions of final acceptance of the project/stage from the beginning, as part of the FK. The most significant results related to both experiences regarding the application of the new method are summarized in Table 1. A specific distinction between planning and execution is presented in order to identify more easily the "what" and the "how".

**Table 1.** Comparative analysis of the planning and execution phases.

<table>
<tr><th rowspan="2"></th><th rowspan="2">Concept</th><th colspan="2">Contribution</th></tr>
<tr><th>Case 1</th><th>Case 2</th></tr>
<tr><td rowspan="5">Planning</td><td>Full Kit</td><td colspan="2">Extensive use:<br>Relevant issues are not forgotten<br>Fast and easy to use<br>Defines and limits the amount of remaining work. As a result, focusing efforts becomes easier<br>Warrants mutual consistency of phases<br>Supports the strategy of the project</td></tr>
<tr><td rowspan="2">Decoupling</td><td colspan="2">Extensive use</td></tr>
<tr><td>Based on experience and on agreements with the customer</td><td>Based on internal estimates (the foundation for estimates is not always precise/strong)</td></tr>
<tr><td>Decomposition</td><td colspan="2">Sequential<br>Impels development of an explicit and consistent project strategy<br>As a result, essential questions related to planning issues arise sooner; more options for decisions and time to make decisions are available.</td></tr>
<tr><td>Templates</td><td>Extensive use of templates:<br>Relevant issues are not forgotten<br>Fast and easy to use<br>Based on experience ("lessons learned")</td><td>Limited use of templates: only in repetitive phases or in phases similar to projects carried out in the past (i.e., the methodology is useful at a generic level).</td></tr>
<tr><td rowspan="4">Execution</td><td>Full Kit</td><td colspan="2">Accurate visibility of the preparation of each phase<br>Early detection of problems related to the phase preparation and potential impact on on-time start</td></tr>
<tr><td>Decoupling</td><td colspan="2">Attenuation of deviations in preceding phases</td></tr>
<tr><td>Decomposition</td><td colspan="2">Early detection of potential impact on later phases<br>Updated view of the general situation of the project</td></tr>
<tr><td>Templates</td><td colspan="2">Accurate and updated view of the evolution of each phase<br>Accurate perspective of the performance of resources involved in each phase</td></tr>
</table>

This perspective revealed an especially striking feature. With the new approach, the FK managers asked the same questions as before, but sooner (often right from the beginning). Furthermore, most of the time, the answers to such questions were known (but not communicated until asked), or led to earlier decision-making. This indicates that some of the main sources of uncertainty lie in the organization's way of proceeding, and not in external causes. Consequently, improving this aspect is in the hands of the organization.

Finally, the comparison of both cases revealed another element of interest: the impact that software can have on the success of implementation. While Case 1 used commercial software to implement the new method, for Case 2 a basic tool was developed to cover basic needs. However, the limitations of the tool meant that it provided insufficient support, and somehow hindered the implementation process. This is a lesson learned since the lack of support can put the implementation of a suitable method at risk.

In terms of the study's human aspect, the analysis carried out required a great dedication from and presence of the researchers. This involvement allowed for a first-hand observation of the investigation, such as behaviors and reactions to various situations and problems. Despite being two very different companies, level of maturity and company culture had a significant influence on the actual habits and behavior of the members of the organization. This obviously influences results, but what is especially interesting is the impact that maturity and culture can have on the success of implementation.

### *5.2. Final Conclusion*

The approach measured in this study may be useful for design projects, especially when performing in uncertain contexts. Its main virtues are simplicity, ability to deal with uncertainty, and adaptability to diverse and/or changing contexts. Rooted in the very nature of the approach is the consistent combination of project strategy and structure. Thus, this approach enables easy project articulation. It provides a twofold vision in the form of an overview of the entire project, and a detailed perspective of its operative phases.

It has been verified that the adoption of these concepts was affordable for two organizations with highly technical resource profiles and different management capabilities. Therefore, the approach may be considered as helpful for organizations with difficulties in managing projects. For those companies with a medium-high level of maturity in PM, it can be helpful to simplify and strengthen their current practices. In contrast, those companies with a lower level of maturity can adopt the methodology, which is capable of improving their management, relatively quickly and easily.

### *5.3. Limitations and Future Research*

The scarce literature on this topic, its incipient development, and the limited scope of this study mean that the work carried out has evident limitations. First, the study was limited to the design phase. Design-related activities are a significant source of uncertainty that is transmitted downstream. Nevertheless, future applications of the same method with a greater scope would contribute to a better evaluation of its true influence. Furthermore, the application to the entire life cycle of the project, as well as to other sectors, would broaden findings. Similarly, the multiproject perspective has only been partially analyzed. An extension of this study, based on a holistic perspective, would provide a more complete systemic vision, which could lead to new insights. In particular, we encourage researchers to develop hybrid research, combining different approaches. We believe that this would contribute to a deeper understanding of the potential and synergies derived from combining the strengths of approaches that have been developed separately.

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