Adapting project management maturity models for the Industry 4.0

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Title

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Felipe Sanchez, Davy Monticolo, Eric Bonjour & Jean-Pierre Micaelli. Adapting project management maturity models for the Industry 4.0. (2019). In Proceedings of Project Management Congress: Research meets Practice. Towards Project Management 3.0 (pp. 637-656). 11-12 April. Delft University of Technology.

Abstract

Abstract: Companies are currently facing substantial challenges with regard to Industry 4.0. Consequently, increasing complexity on all firm levels creates uncertainty about organizational and technological capabilities and adequate strategies to develop projects. In order to adapt to this environment, companies are moving from operations-centered business to project-driven business. This change requires evolution in project management. Researchers and practitioners have created maturity models to evaluate and improve project's organizations, but they did not specify any methodology to adapted models face to this technological transformation. Hence, this paper proposes an approach to understand the principles of classic project management maturity models (P3M). Then to answer how it is possible to create a new structure applicable in the emerging framework of Industry 4.0 agile projects. Given that technology is changing fast, it is hard to predict how business and project management will be structured in the next years. Instead, this research wants to know what it is not going to change. This is the reason why this work advocates reasoning from invariant principles of project management to propose the new evaluation framework. Finally, this research defines its limitations and future directions.

Keywords

Project Management, Agility, Maturity Model, Adaptation, Industry 4.0.

Introduction

The Industry 4.0 Context

“*Industry 4.0’* was born as a word to qualify for the next wave of manufacturing. This concept describes the digitization of the entire value chain and the interconnection of people, objects and systems through real-time data exchange (Ganschar, Gerlach, Hämmerle, Krause, & Schlund, 2013). This technological context is developed due to productive organizations based on specific technocratic solutions, e.g. flexible production cells, cobotics, autonomous robotics, augmented reality, extensive customization, the internet of things and services, big data, etc. Those organizations are called smart factories (Shrouf, Ordieres, & Miragliotta, 2014). They invest massively in cyber physical systems (mechanism controlled by computer algorithms) to gain competitiveness satisfying the following requirements: agility, spatial proximity to the end user, extreme reactivity, variability, eco-efficiency, medium size, connectivity to all types of networks, etc. (J. Lee, Kao, & Yang, 2014) .

Industry 4.0 would be of such an impact that it would transform the industrial world and then each firm’s business model. In fact, under Industry 4.0 pattern, old firms (insiders) may develop new products and services while new firms (outsiders) may propose disruptive services, e.g. shared plants rented by different manufacturers, learning software to optimize on real-time the use of capital goods, etc. (Yue, Cai, Yan, Zou, & Zhou, 2015). Moreover, this new concept has some weaknesses, e.g. uncertain profitability, technical complexity and risks, non-estimated impact in terms of abilities and work organization, etc. Industry 4.0 proponents also fail to mention that the concept they promote suppose new projects and business processes features.

Research Question

This work defines 'agilification' as a process by which organizations gain agility to adapt to the new context of Industry 4.0. Agility, defined as the ability to behave quickly, with celerity, promptness, astuteness, reactivity, flexibility, dexterity, etc., Agility is a scalable property; it qualifies how organizations, even large ones, should behave. Used first to characterize manufacturing systems, then diffused in many sectors, organizational agility refers to the *'ability to change project plan as a response to customer or stakeholders needs, market or technology demands, in order to achieve better project and product performance'* (Conforto, Amaral, da Silva, Di Felippo, & Kamikawachi, 2016).

In the field of project management, agilification supposes a shift from "Bureaucratic Project Management" (BPM) also called classic, heavy or traditional (Charvat, 2003) to "Agile Project Management" (APM) (Conforto et al., 2016; Dalcher, 2011). BPM depends on linear lifecycle of the project, it is plan-driven and characterized by a requirement, design, build methodology of development (Boehm & Turner, 2003). BPM is based on predefined, detailed and mandatory roles, deliverables and procedures designed by project experts belonging to the 'techno structure' (Mintzberg, 1980). Project managers are supposed to implement these predefined procedures as closely as possible. By contrast, APM is focused on '*adhocratic'* iterative structures (L. Lee, Reinicke, Sarkar, & Anderson, 2015; Rose, 2010) e.g. teams or communities, exhibiting reactivity, creativity, flexibility. These collective actors work autonomously by acting iteratively and by using shared resources or specific Information Technologies (IT) (Elonen & Artto, 2003) Under APM, project managers are enablers facilitating the teamwork.

This research considers the shift from BPM to APM as a smooth process. Agilification consists in moving the center of gravity of project management towards the agility pole in order to break with BPM. One of the theoretical reasons explaining our conception comes from the work of theorists of 'organizational ambidexterity' (Jansen, 2005) who explain that organizations combine 'exploitation of old certainties' and 'exploration of new possibilities' (March, 1991). In the case of project management, ambidexterity has a specific meaning: project management balances the implementation of predefined processes (exploitation, as BPM highlights it) and the guidance of improvisation (exploration, as APM mentions it). Empirical works show the complementary between APM and BPM. For instance, whereas APM has a significant impact on projects" efficiency, stakeholders' satisfaction, and internal perceptions (Serrador & Pinto, 2015), it does not concern all areas of the project management (Whyte, Stasis, & Lindkvist, 2016). In large companies designing complex products, BPM remains dominant in risk or contracts management. Therefore, one issue arises: What parts of BPM can be used to make agilification effective. We defend that a key instrument of the BPM, which is the Project Management Maturity Model (P3M), can be adapted to APM. Nevertheless, existing P3Ms must need some substantial improvements and changes. Therefore, the research questions in this paper is: How is it possible to adapt project management evaluation to an agile context in Industry 4.0?

Methodology

Two sources will contribute to constructing our proposed methodology. The first one, serves as theoretical foundation by pointing out the relevance of project management maturity models (P3Ms), it concerns our analysis of both existing P3Ms and their limits within the Industry 4.0 characteristics. The second source is empirical. Working in a project management consulting firm (Sopra Steria), we had the opportunity to analyze how several projects were assessed by process auditors and what improved insights they gave to their customers, i.e. large firms. We conducted 23 semi-structured interviews to 11 experts with 6 - 20 years of experience in the industry in order to understand the patters in the current practices of project management for Industry 4.0. We collected their knowledge in project management in the case of agile organizations, smart factories included. Due to budget and time restrictions and personal privileged access, only personnel in French organizations were interviewed. The subjects had different roles in the organization, directors (18%), senior consultant in project management (57%), and project managers (27%).

This paper is structured as follows: in section 2, we will present a brief view of BPM principles and APM foundations, with a focus on "*Scrum*" (Setpathy, 2016). In section 3, we will explain why the P3M consistent with BPM is not fully compliant with APM. In section 4, we will go off the blocking points to propose a conceptual model of a P3M coherent with both BPM and APM. Finally, we conclude about main findings and limitations.

BPM and APM Principles

Project Management Maturity Models (P3M) For BPM

Projects are constrained in terms of operational performances, e.g. delivery time, direct cost, quality, risk minimization, etc. Indeed, several actors or stakeholders, different functions or business areas are involved in a given project. For the PMI (Project Management Institute), projects have specific management rules to prepare, to implement and to close them. Thus, project managers implement processes whose performances can be qualified, quantified, measured, benchmarked and improved. Maturity is one of these performances (Ramirez, 2009).

Since the beginning of the 2000s, experts have been developing more than 30 different types of Project Management Maturity Models (P3M) (Grant & Pennypacker, 2006). The Capability

Maturity Model Integration (CMMI), created in the 1990s by the Software Engineering Institute, uses five levels. Other models have taken up this proposal (Andersen & Jessen, 2003; Grant & Pennypacker, 2006). They also use a collection of projects' knowledge areas. The PMBOK® identifies ten of them, as well as the Berkeley Process Management Process Maturity Model or (PM)2 (Kwak & Ibbs, 2002), e.g. cost, integration, procurement, Human Resource, deliverables, risk, etc. The third characteristic is a list of practices to check. (Kerzner, 2017) Project Management Maturity Model suggests a list of 183 items. The Project Management Solutions Project Management Maturity Model has a longer and more detailed list of items (Grant & Pennypacker, 2006). PMI's Organizational Project Management Maturity Model (OP3M) proposes 600 best practices usable as benchmarks. Once the practices belonging to different project domains checked, auditors can synthesize the data in a tool called a maturity grid. The scored grid helps managers to formulate expectations in terms of practices' improvements. After our analysis of different P3M this work notes that they share the same principles.

Principle 1.B: The achievement of Project Key Performance Indicators (PKPI) describe projects' success. This PKPI is supposed to drive projects' reliability, efficiency, etc.

P2.B: The fact that project's managers implement (or not) certain practices explains projects' successes (Cooke-Davies, 2002).

P3.B: The practices are tasks producing well-defined outputs, *e.g.* Work Breakdown Structure (WBS), and by extension: working rules, *e.g.* once the Product Breakdown Structure (PBS) is done, create the WBS.

P4.B: Project experts define a process as a collection of tasks (or practices, routines) and working rules belonging to the techno structure.

P5.B: Several process audits missions enable to identify the best practices improving organizations' capabilities, *i.e.* their recognized ability to implement routines differentiating them from nearby organizations, *e.g.* competitors, followers, etc.

P6.B: There is a scale of perfection dividing the maturity levels from lowest to highest. Without any predefined process, the project managers improvise harmfully, and then they gain maturity by conforming to a pattern created by experts, creating improved ways of performing processes.

P7.B: project management concerns different separated domains (syn. areas). Project managers' work has then a wide scope; they must be aware of different aspects, implement various practices, *e.g.* technical specifications, team animation, cost reporting, etc., and produce several types of deliverables, *e.g.* bill of requirements, scheduling charts, scorecards, contracts, meeting reports, etc.

The BPM we have presented concerns many sectors and types of organizations; it is then difficult to question its effectiveness. Nevertheless, does it remain relevant when project management want to become agile? We will show how agile projects may uncover a contrary conception.

Agile Project Management, the Case of Scrum.

Experts in software engineering have noted that some projects based on BPM sometimes fail to develop products satisfying clients' needs or timing. Therefore, they proposed a model which emphasizes in agility (Beck, 2000). Despite it has a very marked IT (Information and Technology) character, many organizations recognize this agile feature as a reference, even if their core business is not software but manufacturing.

There are different agile frameworks, the one we will focus on this paper is "*Scrum*" (Setpathy, 2016). Scrum creators propose a body of knowledge based on clear technical and management principles. The project management method they promote is "*an adaptive,* *iterative, fast, flexible, and effective methodology designed to deliver significant value quickly and throughout a project* […] *A key strength of Scrum lies in its use of cross-functional, self-organized, and empowered teams who divide their work into short, concentrated work cycles called Sprints*" (Setpathy, 2016). Whereas Scrum targets the project, it is clear that its principles differ from those of the BPM.

P1.A ("A" for "agile"): Agility drives projects' success, especially in terms of customer's value (usability, price, etc.) and lead-time (project reactivity).

P2.A: The fact that the project managers and the teams implement collective and time-focused practices and working rules may explain projects' successes. Moreover, the project manager is not a conductor alone. He is responsible for the "*roadmap*" definition and planning, and he collaborates with the "*product owner*", who is the customers' spokesperson, and the "*scrum masters*" who leads teams' meetings. In addition to using commonplace tools, these actors rely on a pool of resources made of working environment, *e.g.* rooms for stand-up meetings ("*daily sprint"*), visual management devices, *e.g.* "*scrum board*", rapid or virtual prototyping tools, etc.

P3.A: Agile practices enable teams to develop in short times intermediary prototypes satisfying prioritized requirements ("*sprints*"). Scrum assumes that the bill of requirements can be breakdown into modules called "*product backlog*".

P4.A: Scrum atom is not a task, but a loop occurring in a very constrained period ("*time boxing*"). Scrum's creators did not elaborate the feature of this loop. Nevertheless, we can assume that it is made of an "*ad hoc processes*"(Object Management Group (OMG), 2011) or explorations; it is based on the continuous collaboration between projects' actors, and its control is autonomous, *i.e.* made of self-organization and "*mutual adjustments*"(Mintzberg, 1980).

P5.A: Scrum experts identify APM's best principles and resources.

P6.A: There is no perfection scale of agility. Nevertheless, if every agile project requires "*core roles*", *e.g*. project manager, scrum master and product owner; since an organization's project portfolio reaches a certain size, APM also requires "*non-core roles*", *e.g*. "*Scrum Guidance Body*" and "*Chief Scrum Master* [who] *is responsible to coordinate Scrum-related activities*" (Setpathy, 2016).

P7.A: There is no clear mention of the project's domain aspect of the loops.

Once the agile pattern has been illustrated in the case of Scrum, it is now advisable to return to compare BPM's principles about project management maturity *vs*. APM's ones.

Limits of typical P3M faced to the industry 4.0 context: BPM vs. APM

P1.B *vs.* P1.A – PKPIs definition exposes the first contradiction. Under BPM, the process conformity guarantees by itself the other performances of the project. Moreover, as part of the bureaucratic tradition, practices are supposed to be safer and more efficient since they are detailed as precisely as possible. By acting conformably, the project managers reduce the loops, conceived as perturbations slowing down the expected progress of the predefined project. This conception contrasts with APM, which focuses on customer's value, lead-time, and teams' dynamics than conformity with predefined processes. Under APM, projects are supposed to be extremely intensive; the project organization develop the most valuable deliverables are produced as soon and as frequently as possible (Conforto et al., 2016).

P2.B *vs.* P2.A – Both BPM and APM assume that projects are manageable entities, explaining why the implementation (or not) of certain practices leads to success (*vs*. fails). The current guidance of BPM and APM is not the same: exploitation and standardized process implementation for BPM *vs*. exploration and improvisation for APM. In both cases, experts and theorists build and improve.

P3.B *vs*. P3.A – The temporal and spatial scales (granularity) BPM takes into account differs from those targeted by APM. Scrum has a finer granularity than BPM, it is based on weekly work, with sprints and scrums management, and even daily work, with stand-up meetings animation. APM is therefore closer to its operational actors and its monthly, weekly or even daily projects' dynamics.

P4.B *vs*. P4.A – BPM states that the practices and the working rules are atoms, which are assessed independently and be replicated as series parts. On the contrary, Scrum refers to loops, which have more behavioral features. Furthermore, Scrum experts point out the key role of shared resources, and then organization's digital maturity (Schumacher, Erol, & Sihn, 2016). Another point concerns the conception of openness. Under BPM, it concerns only the benchmarks of best practices to apply as such (see P5.B). Maturity level 5 mentions another term referring to openness, which is innovation (see P7.B). Nevertheless, innovation concerns incremental procedural improvements; it is mentioned only once the lower maturity levels have been reached, and therefore project's managers implement standardized process. APM is contradictory with this conception: project's actors are creative and empowered individuals, improvisers, not agents executing mandatory detailed procedures.

P5.B *vs*. P5.A – Both BPM and APM explain a part of the organizations' capabilities by the way their projects are managed. However, the capabilities under study differ under these two types of project management. Under BPM, the capability concerns the ability to implement mandatory processes. On the contrary, APM theorists are attentive to the incentives, to the opportunities, but also to temporal constraints or the ones derived from collaboration, creation, etc., referring then to organizational openness.

P6.B *vs*. P6.A – The comparison clearly goes to the advantage of BPM, which is based on work initiated since the 1990s on Quality Management, and then process maturity assessment. The maturity of agility is clearly a point to develop, as we will see in section 5.

P7.B *vs.* P7.A – Under BPM, projects' domains are groups of processes. As the process models are refined, the size of the collection of domains grows.

Building Methodology to Adapt P3M for APM

Our first presupposition is that every P3M should be based on an ontological basis, i.e. an explicit conception of the project's domain made of specific entities (projects, actors, process, practices, deliverables, resources, etc.), properties (conformity, agility, reactivity, maturity, etc.) and descriptive (is a, is part of, etc.) or causal relations (this PKPI explains this other PKPI, etc.). We suggest that a generic entity called "behavior" can be the base of these ontological fundaments; project management ontology is then a type of behavior ontology. The behavior is present in many disciplines: there are then various instances. The behavior is an entity (1) labeled with an action verb describing what is done. (2) It is related to an actor (individuals or collective with a role, e.g. technical teams) or an organizational structure. (3) It is triggered when a given event occurs (stimulus). (4) It produces an observable output (response), e.g. a deliverable. (5) It occurs in a given context made of altars and resources. (6) It is driven by internal variables (goal-oriented). (7) It follows given modalities, maturity included. This general conception of the behavior has different instances depicting different parts of the P3M.

The first instance we can derive from the behavior ontology is the perfection scale. Made of maturity levels (see P6.B), it refers to modalities of the behavior to check. Any level of the perfection scale qualifies how project managers should behave. Do they improvise? Do they conform to an existing pattern? Do they improve the ways of performing processes? We have also instances of the behavior when we mention projects' domains (see P7.B). Any of them defines the content of the behaviors projects managers realize: operations vs. transactions, e.g. PBS definition vs. procurement. The domains also mention the results of their behaviors, e.g.

deliverables, contracts, interpersonal relationships, etc. The behavior has a third instance referring to the types of roles individuals play. They exhibit specific behaviors by managing organizational structures, managing projects, auditing processes, etc. The usual notion of levels of decision refers to the behavior. The strategic level concerns the development of the organizational structure's capability; the tactical level refers to process maturity improvement; the operational level corresponds to the leading way projects are led, and the practical level concerns the way tasks are performed in projects.

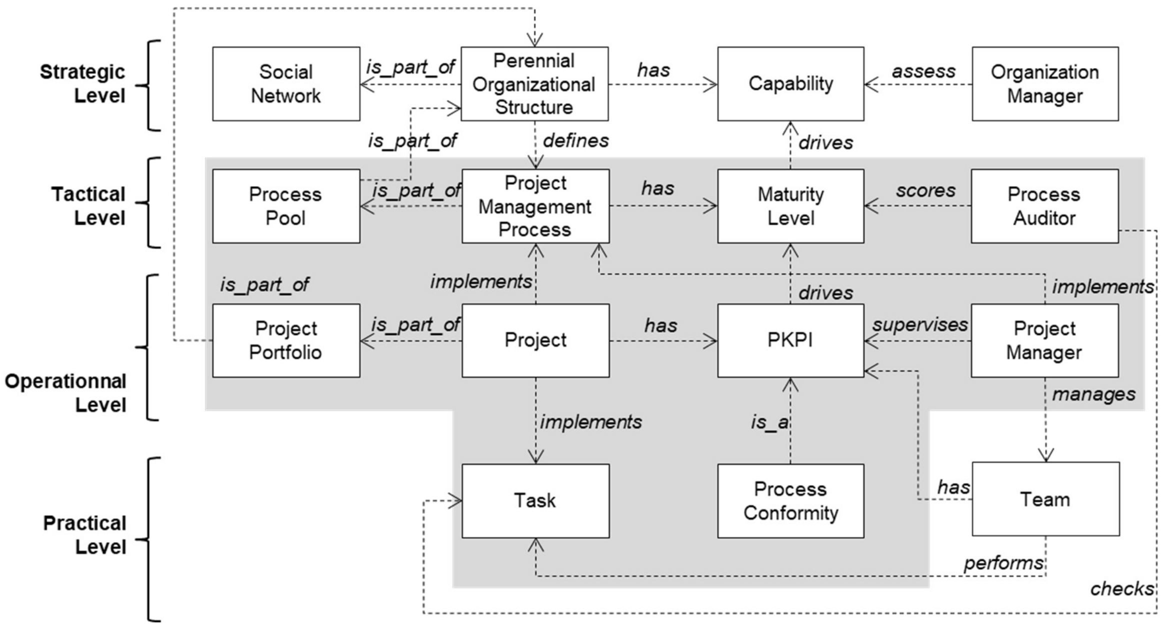

Fig.1. Maturity Model Conceptual Framework.

We can elaborate the figure 1 by detailing the content of project management process (P7.B). As mentioned, we conceive each project's domain as a package clustering specific behavioral instances. Thus, a first package contains the outputs of project managers' activities, e.g. projects deliverables, but also the outcomes, e.g. new tasks considered as best practices. The goals guiding project managers' awareness (project requirements, PKPIs, etc.), resources (data integration, logistics, Human Resource, etc.), and social configurations made another package. The principles proposed in the last section built this maturity methodology by discussing with project management experts, and by interviewing experts. We have detected how P3M had common assessment principles. First, we adapted from the PMBOK® a preliminary conceptual model describing how process auditors evaluate maturity levels. We based on two phases the construction of a model.

Phase 1. Set construction rules from behavior invariants.

We have also identified several similar practices across all P3Ms. To simplify the assessment process and keep only the practices that will be necessary to check in different types of projects. We have selected those key practices, which their properties do not change if the project becomes agile; we called them invariants. Even if the project management organization is changing, different project management methodologies presents the same invariants properties.

We realize that any project can be then described following a chronology made of three *momenta*: prepare (before the project), monitor and control (during the project), valorize and sharing (during and after the project). This chronology contains the practices to check; they belong then to the packages related to the project's preparation, monitoring and valuation. See Figure 2. Another behavior's properties give details on which the practice to check is realized (or not) and then assessed. First, activity granularity (G) concerns the level of details that may be used to describe the outputs of project management activities, e.g. what has been done to accomplish the realization of the planning? Second, frequency (F) concerns the actors and tools necessary to complete the PM activities, e.g. who is updating the planning? Third, resources involvement (R) concerns the temporality of the PM activities, e.g., how often is the planning updated or changed?

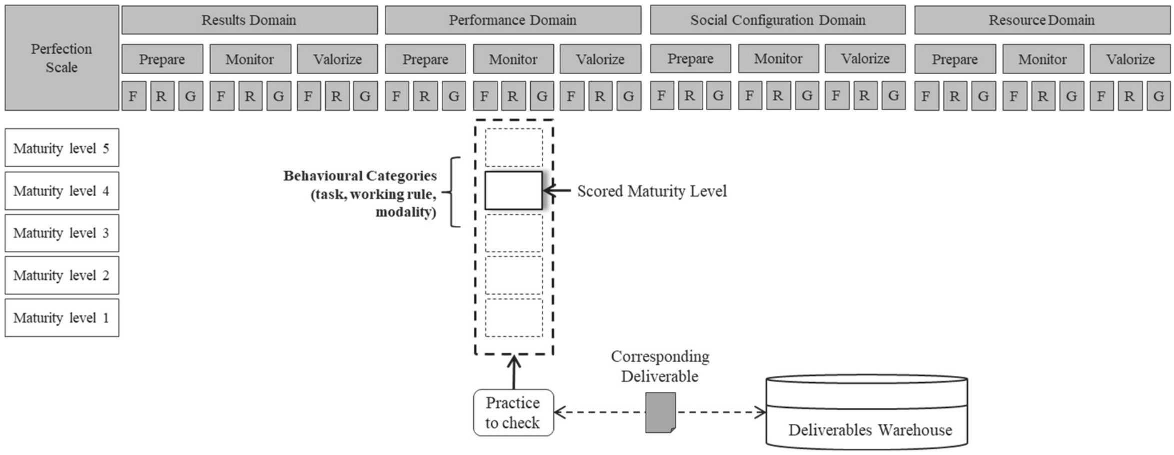

Fig.2. *Example of the Evaluation structure*

The checking process should prevent the auditors from questioning only a selected group of persons that "should" have all the knowledge of the project. Instead, this model should allow the use of data coming from the project management supports (PM software, cloud-based team collaboration tools, and connected objects) to help the auditor deduct if the "best practices" of project management were put in place or not (checking process). Because activities in Industry 4.0 are generating data everywhere every day, project management data should ratify the checking process.

Phase 2. Define the perfection scale

Existing P3Ms should define explicit rules to move from a given maturity level to the next one. For instance, a discrete rule is to check if all practices at the current level have been positively observed by defining an external unit of measure, e.g., "checked experience". If the value of this premise is true, then project management can move to the next maturity level in that domain.

The levels we have taken into account have the following semantics: no implemented (level 1), defined and implemented (level 2), measured and analyzed (level 3), managed and contextualized (teams can manage complexity emerging from interdependencies with other projects) (level 4), and capitalized practices for the whole organization or the entire industry (level 5).

For instance, the maturity levels 1 and 2 indicate that the project management activities are still informal. Once the project arrives to maturity level 3 it is getting data to compute required maturity criteria. As an example, the project manager should have quantifiable indicators (i.e. revenue, or lack thereof) specifying if their internal tools are significantly lagging behind the competition. The idea is to replace useless, time-intensive bureaucracy like internal surveys and audits with a feedback loop that generates value when it works and quickly identifies problems when it does not. Maturity levels 4 and 5 imply that several members of the project are in constant communication, measuring gaps and checking the consistency between activities of the project to ensure the participation of stakeholders and the openness of the project. Furthermore, level 5 implies constant implementation of feedback received by end users, or key stakeholders. At this level, openness can act over the entire industry. They are capable of turning every single piece of the company into a separate platform and thus opening each piece to outside competition, or coopetition. Any enterprise working with high maturity project management (level 5) should rebuild its internal tools as an external consumable service.

Conclusion

After analyzing in detail most common P3Ms, we discovered that those models lead to a contradiction with the characteristics of Agile Project Management in Industry 4.0, where decentralized information is and shared in real time, teams work in networks and consequently maturity should be measured differently. Industry 4.0 needs to focus on developing projects as fast as possible but maturity models tend to slow down the project management evaluation and improvement process. As an alternative, our proposal looks for evaluating only invariants across project management transformation. We advocate reasoning from invariant principles of project management. Given that technology is changing fast, it is hard to predict how business and project management will be structured in the next years. Instead, we question what it is not going to change in the next years. Those invariants guarantee better project evaluation because they can be shaped around the practices that are stable in time. Supplementary, this paper has proposed a new P3M construction methodology that aims to adapt project management evaluation to this new changing environment.

Agile project management evaluation is not completed; further research should then concern it. APM ontology should be elaborated, which extends and clarifies the entities and properties we have mentioned. Moreover, according to the contextual characteristics of the project, the required maturity level should not be the same. Some projects will need higher maturity to improve their performance and others are 'good enough' with a lower agile maturity level. There is no practical way to measure whether it is necessary to stop in one level of maturity for a certain project and a certain organization, or if it is necessary to keep improving up to level n+1, or n+2 in order to get maximal project performance.

Acknowledgment.

This work has been carried out under the financial support of the French National Association of Research and Technology (ANRT in French – convention CIFRE N° 2016/0778) as well as Sopra Steria. We want to acknowledge Sopra Steria Consulting for helping us to define the proposed method.

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