The Evolution and Influence of Project Management Theory and Practices: a process network analysis

Alessandro Annarelli (alessandro.annarelli@gmail.com)
Sapienza University of Rome
Department of Computer, Control, and Management Engineering
Via Ariosto 25, 00185, Roma, Italy

Cinzia Battistella
University of Siena
Department of Information Engineering and Mathematics
Via Roma 56, 53100, Siena, Italy

Fabio Nonino
Sapienza University of Rome
Department of Computer, Control, and Management Engineering
Via Ariosto 25, 00185, Roma, Italy

Giulia Palombi
Sapienza University of Rome
Department of Computer, Control, and Management Engineering
Via Ariosto 25, 00185, Roma, Italy

Abstract

This paper sets out a key contribution by analysing the development of Project Management theory and knowledge. By mean of a research conducted on the Project Management Body of Knowledge (Project Management Institute), authors employed tools and methods from Social Network Analysis to represent and analyse this standard of Project Management and its processes as a graph with nodes. Results of the research shed light on the evolutionary dynamics of Project Management, showing how through different years and (six) editions of the standard, relevant processes, Knowledge Areas, and best practices changed, reflecting different views that shaped the evolution of the field.

Keywords: Project Management Evolution, Network Analysis, Central Processes

Introduction and background

Project Management (PM) became an increasingly consolidated discipline for managing activities of considerable economic importance and growth in almost all organizations across different sectors, industries and countries (Turner *et al.*, 2010; Winter *et al.*, 2006). Moreover, PM has been also receiving a considerable amount of research starting from the 1980s and the trends are likely to continue in the future (Kwak and Anbari,

2009). Nevertheless, it is one of the most recent managerial disciplines as the first PM methodologies appeared in 1930s, but only starting from the end of the 1950s the management of engineering projects would lead to standardized tools, practices and roles, and the emergence of effective models (Garel, 2013). PM discipline includes many best practices developed and experienced by practitioners and formalized by scholars during time, also coming from different management fields, above all Operations Management (OM). In particular, mutual influence historically came from several project typologies, e.g. re-engineering business processes, developing new product and services, and improving operations quality.

Going further, discipline evolved through years, and its advancement can be represented by the progression of the standardized best practices organized in Knowledge Areas (KAs) and processes inside the book Project Management Body of Knowledge (PMBoK) developed and edited for the sixth time in 2017 by Project Management Institute (PMI), world's leading organization in PM.

The aim of the present research can be synthetized by the following research questions:

- How is the PM theory evolving?
- How did best practices, processes and Knowledge Areas change through time?
- Which are the most important best practices, processes and Knowledge Areas in PM theory?

Methodology

We considered the PMBoK, initially published in 1996, and updated in 2000, 2004, 2008, 2013 and, most recently, in 2017, as representative of the evolution of PM best practices through the years. Each update brought a progress and enlargement of contents, organized in processes belongings to specific groups and KAs.

Network Analysis of PMBoK Processes

In order to define the most important processes in PM theory (according to PMI), we employed methods and indicators from Social Network Analysis. We analyzed all the PM processes described in the six editions of PMBoK and considered them as nodes of an oriented network, with incoming and outcoming links showing, respectively, previous and following project processes.

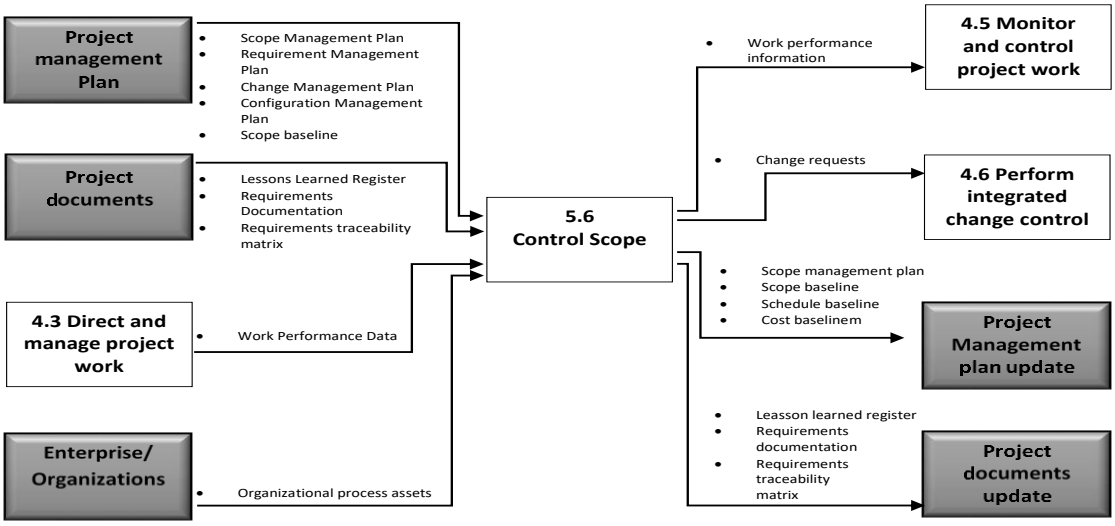

Figure 1 – Example of network of processes of PMBoK

Then, we constructed and organized data in adjacency matrices, where rows and columns reported the names of each process and values in the cells indicate the presence of at least a link among the processes. Table 1 contains a section of the adjacency matrix as an example.

Table 1 – Example of adjacency matrix

	4.3	4.4	4.5	4.6	4.7	5.1	5.2	5.3	5.4	5.5	5.6	Enterprise/ Organization	Project Documents	Project Management Plan
4.3		1	0	1	0	0	0	0	0	1	1	1	1	1
4.4	0		0	0	0	0	0	0	0	0	0	1	1	1
4.5	0	0		1	0	0	0	0	0	0	0	0	5	1
4.6	1	0	0		0	0	0	0	0	0	0	0	1	1
4.7	0	0	0	0		0	0	0	0	0	0	1	1	0
5.1	0	0	0	0	0		0	0	0	0	0	0	0	2
5.2	0	0	0	0	0	0		0	0	0	0	0	2	0
5.3	0	0	0	0	0	0	0		0	0	0	0	5	0
5.4	0	0	0	0	0	0	0	0		0	0	0	2	1
5.5	0	0	1	1	1	0	0	0	0		0	0	3	0
5.6	0	0	1	1	0	0	0	0	0	0		0	3	5
Enterprise/ Organization	2	2	2	2	1	2	2	2	2	0	1		0	0
Project Documents	8	5	10	4	12	0	3	3	2	4	3	0		0
Project Management Plan	1	1	1	5	1	2	3	1	1	3	6	0	0	

Among network measures, centrality allowed us to analyse and understand processes' role and importance. An important distinction must be made between local and global centrality: a point is locally central if it presents a high number of connections with surrounding points, while it is globally central if it has a key position in network's overall configuration. SNA offers different indicators to evaluate centrality of a node (in our analysis a process), according to different attributes being the object of the analysis. Local centrality of a process can be measured by in-degree centrality, defined as the number of incoming connections for each node, and out-degree centrality, which represents the sum of outcoming connections. The first index allowed us to identify dependences and constraints among processes, given that a process with a high In-Degree is more constrained by previous activities and has a higher probability of being late on scheduling; on the other hand, a process with a high out-degree can have an influence on several following processes, and can have a strong influence on project scheduling. Synthesising:

- In-degree centrality: how much a process is directly influenced by other processes;
- Out-degree centrality: how much a process directly influences other processes.

Closeness and betweenness centralities can measure global centrality of a process. Closeness represents the reciprocal of the farness, i.e. the sum of the lengths of the geodesics of a node to every other node. In case of an asymmetric matrix, we have an incoming farness, and consequently an In-closeness, and an outcoming farness and consequently an Out-Closeness. For a given process, In-closeness centrality measures how many indirect steps are needed for all other process to "reach" the process, while Out-closeness measures how many indirect steps the process requires in order to reach all the other processes in the network. The Closeness is the sum of the reciprocated distances so that infinite distances contribute a value of zero. Synthesising:

- In-closeness centrality: how much a process is indirectly influenced by other processes;
- Out-closeness centrality: how much a process indirectly influences other processes.

The fifth index of Centrality we employed is the Betweenness, which is equal to the number of shortest paths from all vertices to all others that pass through that node (process): a high degree of Betweenness implies a large influence on the network. Synthesising Betweenness shows the brokerage level of processes in a network; for a given process, it is mathematically defined as the number of shortest paths between any two processes that "pass through" the process analysed. In our study, we used the so-called Flow Betweenness, a more advanced measure of the contribution of a vertex to all possible maximum flows, i.e. the sum of the amount of flow between two vertexes which must pass through the node for any maximum flow (Freeman et al., 1991).

Starting from the six adjacency matrices, we calculated the value of the five Centralities for all the processes and analyzed their nature and linked best practices with the highest degrees as having a key role in PM practice. For instance, as regards the example reported before, the value of the centrality indexes for the processes are shown in Table 2.

Table 2 – Example of five centrality indexes for PM processes

	Out-Degree	In-Degree	Out-Closeness	In-Closeness	Betweenness
4.3	14	13	108	114	19,22501564
4.5	3	9	120	115	8,102953911
4.6	10	24	119	103	17,15377045
5.6	5	35	119	89	34,70240402
Enterprise/ Organization	13	0	141	280	0
Project Documents	0	1	280	160	0
Project Management Plan	1	0	174	280	0

Historical analysis of PM's central processes, tools and techniques

From the total group of central processes identified, we selected the first 10% of processes with the highest value for each index calculated obtaining a set of almost 20-30 central processes (some processes appeared in the "top-five" for more than one index) for each edition of the PMBoK, with the most recent editions showing a higher number of central processes. This provided us with a final set of 117 central processes, also considering the recursiveness of some processes, with 63 unique processes.

Since every process uniquely belongs to a KA, the analysis performed allowed us to trace the relevance of these KAs throughout PMBoK editions, according to the number of central processes in each.

Following the analysis of central KAs and PM processes, the subsequent step of analysis focused on best practices of PM, labelled as Tools and Techniques in the PMBoK. Each process has a set of relevant best practices indicated as useful and important while conducting the activities related to that process, in the context of PM. From the list of 63 processes we derived a list of 166 unique best practices (which become 434 if we consider repetitions, as for processes).

Results of the analysis

The following Table provides a synthesis of the major differences in PMBoK standard as emerged through the years.

Table 3 – Evolution of PMBoK Standard throughout published editions

PMBoK Edition	1st	2nd	3rd	4th	5th	6th
Process group	5	5	5	5	5	5
Knowledge Area	9	9	9	9	10	10
Processes	37	39	44	42	47	49
Project Integration Management	3	3	7	6	6	7
Project Scope Management	5	5	5	5	6	6
Project Human Resource Management[1]	3	3	4	4	4	6
Project Quality Management	3	3	3	3	3	3
Project Time Management[2]	5	5	6	6	7	6
Project Cost Management	4	4	3	3	4	4
Project Risk Management	4	6	6	6	6	7
Project Stakeholder Management	0	0	0	0	4	4
Project Communications Management	4	4	4	5	3	3
Project Procurement Management	6	6	6	4	4	3
Most important process group	Planning (19)	Planning (21)	Planning (21)	Planning (20)	Planning (23)	Planning (24)
Less important process group	Initiating	Initiating	Initiating & Closing (2)	Initiating & Closing (2)	Initiating & Closing (2)	Closing (1)
Knowledge Area with higher increase of processes		Project Risk Management	Project Integration Management	Project Communication Management	Project Stakeholder Management	Project Resource Management
New concepts/ Knowledge Areas					Project Stakeholder Management Agile approach	Project Resource Management

[1] In the sixth version of the PMBoK the Knowledge Area has been renamed in "Project Resource Management"
[2] In the sixth version of the PMBoK the Knowledge Area has been renamed in "Project Schedule Management"

There are five process groups in each edition, while the number of KAs has been increased in the fourth edition with the introduction of *Project Stakeholder Management Area*. On the other hand, major changes involved the number of processes: this number increased significantly, from 37 processes (in the first edition) to 49 (in the sixth edition).

The second edition of PMboK was published in 2000 and did not show significant differences in terms of number and distribution of processes compared to the first edition, published in 1996. It seems that only few changes affected the KA of *Project Risk Management*, which received an increased attention in the field, as proved by the number of processes (from 4 to 6).

In the third edition, published in 2004, there has been a considerable increase in the number of processes, going from 39 to 44. Apart from minor changes in different KAs, significant changes concerned the Area of *Project Integration Management*, whose processes rose from 3 to 7.

Conversely, the fourth edition (2009) has been the only one so far exhibiting a decrease in the number of project processes, lowering them from 44 to 42, with changes affecting the Areas of *Project Integration Management* (-1), *Project Communications Management* (+1) and *Project Procurement Management* (-2).

The fifth edition (2013) brought two significant changes: the introduction of the Agile approach to PM, and the introduction of a new KA, namely *Project Stakeholder Management*, causing an increase in the total number of project processes to 47.

In the sixth and last edition (2017), two processes were added, respectively in the Areas of *Project Integration Management* and *Project Risk Management*, bringing the total number of processes to 49. Furthermore, in this edition there has been a change in the names of two KAs: *Project Human Resource Management* became *Project Resource Management*, and *Project Time Management* became *Project Schedule Management*. The first and more important change followed a new need in the practice of PM, in order to "ensure that the right resources (physical and human) will be available to the project manager and project team at the right time and place"(PMBok sixth Edition, 2017).

An examination of process groups (also reported in the above table) provided additional and interesting insights: in all the editions, the most important process group has been Planning, encompassing approximately half of project processes in each edition. On the other hand, the less important process groups proved to be *Initiating* (first and second edition), *Initiating & Closing* (third, fourth and fifth edition) and *Closing* (sixth edition).

Table 4 – Evolution of relevance of Knowledge Areas according to processes' centrality

Knowledge Areas	I	II	III	IV	V	VI	
Environmental Factors	4	4	4	5	7	8	32
Project Communication Management	2	2	2	1			7
Project Cost Management						1	1
Project Integration Management	2		6	3	3	4	18
Project Procurement Management	3	3	2	3	2	3	16
Project Quality Management	1	1	1	1	1		5
Project Resource Management	1	1				1	3
Project Risk Management	3	3	2	3	3	4	18
Project Schedule Management	1	1		2	1	2	7
Project Scope Management	2	3	1	1	1	2	10
	19	18	18	19	18	25	117

The above Table 4 shows the evolution of importance and centrality among PMBoK KAs. Considering that the sixth edition introduced new nomenclatures for two KAs (*Project Schedule Management* instead of *Project Time Management* and *Project Resource Management* instead of *Project Human Resource Management*), these have been considered and reported according to the most recent definitions, changing the old names.

We considered as a KA also *Environmental factors*, which gathers together elements of the PMBoK that are comparable to processes, like for instance *Asset*, *Customer*, *Sponsor*, and *Project Documents*. This area shows the highest value of central processes/elements, with a rising trend along PMBoK editions. Though, for the purposes of our analysis, we decided to focus mainly on the other KAs, given that

Environmental Factors are wide spread in all PMBoK editions, and can be considered as less relevant from a theoretical point of view.

Following, KAs with the highest number of central processes are *Project Integration Management*, *Project Procurement Management* and *Project Risk Management*. The last two KAs exhibited a constant number (3 on average) of central processes in all the six editions, while *Project Integration Management* presents a peak of central processes (6) in the third edition: this is an interesting result, also considering that this is the highest number of central processes in a single KA among all editions of the PMBoK, and also considering that in the second edition there was no central process from *Project Integration Management* area.

For the analysis of central processes among PMBoK editions, we focused on Centrality measures from different perspectives: we retrieved and analyzed central processes in each edition, considered separately from the others, and then we compared the dynamics of PM evolution, represented by changes in Centrality throughout PMBoK editions.

The processes that for each PMBoK edition are among most central ones for at least two centrality measures are:

- First edition: *Performance Reporting* and *Overall Change Control* linked respectively to the KAs *Project Communication Management* and *Project Integration Management*;
- Second edition: *Communication Planning* and *Integrated Change Control* related to *Project Communication Management* and *Project Integration Management* KAs;
- Third edition: *Develop Project Management Plan*, *Direct and Manage Project Execution*, *Integrated Change Control* and *Plan Purchase and Acquisition*, all belonging to the KA of *Project Integration Management* except for the last one belonging to *Project Procurement Management* KA;
- Fourth edition: *Develop Project Management Plan, Identify Risks and Collect Requirements* related to *Project Integration Management*, *Project Risk Management* and *Project Scope Management*;
- Fifth edition: *Develop Project Management Plan*, *Conduct Procurements* and *Collect Requirements* associated to *Project Integration Management*, *Project Procurement Management* and *Project Scope Management*;
- Sixth edition: *Conduct Procurement*, which confirms the emerging importance of *Project Procurement Management*.

It is clear that with the third edition in 2004 and its process increment there has been a different distribution of central processes, and this trend became even more evident from the fourth edition (2008).

Indeed before 2004 (first and second edition) the most central processes were:

- *Communications Planning*
- *Contract Administration*
- *Initiation*
- *Performance Reporting*
- *Quality Planning*
- *Risk Identification*
- *Schedule Control*
- *Scope Verification*
- *Solicitation Planning*
- *Source Selection*

Almost all the above processes lost centrality from the third edition (2004); *Communications Planning* and *Performance Reporting* maintained relevance in the third edition, but from the fourth edition (2008) they lost centrality.

Starting from the third edition the following processes became central and maintained this centrality until the most two recent editions (2013 and 2017):

- *Develop Project Management Plan*
- *Direct and Manage Project Work*

From the fourth edition (2008), the following process resulted to be central:

- *Collect Requirements*
- *Conduct Procurements*
- *Perform Qualitative Risk Analysis*
- *Perform Quantitative Risk Analysis*

In the fifth edition (from 2013), only one process emerged as central:

- *Plan Procurement Management*

In the last edition (2017) the following processes became central:

- *Control Procurements*
- *Define Scope*
- *Plan Risk Response*
- *Sequence Activities*

Furthermore, there have been some processes that gained centrality in non-sequential editions:

- *Close Project or Phase (third and sixth edition)*
- *Monitor and Control Project Work (third and sixth edition)*
- *Perform Integrated Change Control (fourth and sixth edition)*
- *Develop Project Charter (second and fifth edition)*

Finally, we wanted to highlight that 20 processes (~20%) emerged as central only in a single edition, with no continuity.

Moving to the analysis of best practices derived from the above central processes, we first took trace of the most important ones in each edition of the PMBoK, with the following results, summarized in the following Table:

Table 5 – Relevant Tools and Techniques compared among editions of the PMBoK

PMBoK edition	Best practices (Tools and Techniques)
I	• *Additional planning* • *Data analysis: stakeholder analysis* • *Data representation: flowcharts* • *Expert judgment* • *Performance measurement* • *Project Management Information System*
II	• *Additional planning* • *Data analysis: variance analysis* • *Expert judgment* • *Performance measurement*
III	• *Audits* • *Expert judgment* • *Project Management Information System* • *Project Management methodology*
IV	• *Expert judgment*

V	• *Data gathering: document analysis* • *Expert judgment* • *Meetings*
VI	• *Analogous estimate* • *Bottom-up estimating* • *Data analysis: alternative analysis* • *Data analysis: cost-benefit analysis* • *Data analysis: document analysis* • *Data gathering: brainstorming* • *Data gathering: interviews* • *Decision making* • *Expert judgment* • *Interpersonal and team skills: facilitation* • *Meetings* • *Parametric estimating* • *Project Management Information System*

Summarizing, the high recurring best practices among all editions are:

- *Expert judgment;*
- *Meetings;*
- *Project Management Information System;*
- *Data analysis: alternative analysis;*
- *Data gathering: interviews;*
- *Decision making;*
- *Interpersonal and team skills: facilitation.*

This result, together with some previous ones, highlights the relevant weight that the sixth edition of the PMBoK had on the evolution of theory in the field, since some of the most important best practices reported in the final list emerged only in the most recent edition of the PMBoK.

Discussion and Conclusions

The results showed how the importance of specific processes changed thought the time and allowed us identify PM practices that contributed to PM evolution.

The first important insight, mainly related to the third Research Question, emerged from the analysis of results concerns the "direction changes" witnessed throughout the years and editions of PMBoK: indeed the third edition (2004) brought some significant changes, like a considerable enlargement of processes' number and a shift in direction, conversely from what emerged comparing the first two editions. With the publication of the third edition the KA of *Project Communication Management* lost importance in favour of an increased interest toward *Project Integration Management* and a new attention to *Project Procurement Management*, with the second KA experiencing a new "interest phase" since the publication of the sixth and last edition. This edition of the PMBoK, as a matter of fact, can be considered the second "turning point" in the evolution of PM theory. Indeed with this edition there has been a rise in the number of central processes, due to a considerable effort in redefining processes among KAs and their reciprocal dependencies. This effort is advisable also in some changes (second Research Question) that affected nomenclatures, first of all the switch from *Project Time Management* to *Project Schedule Management* and from *Project Human Resource Management* to *Project Resource Management*.

Furthermore, changes significantly affected also best practices, the so-called Tools and Techniques, whose names and composition have experimented a revolution: some practices and tools have been gathered together with the creation of new macro

categories like for instance *Data analysis*, *Data gathering*, *Data representation*, *Interpersonal and team skills*. This change among Tools and Techniques gave to some practices a new interpretation and contextualisation in PM theory; moreover, other new macro categories brought a deeper specification of some practices and tools that before were cited together and indistinctly.

Another interesting finding, concerning the second Research Question and best practices, is related to the evolution of the ones acknowledged as relevant: starting from the first two editions, where relevant practices were mostly referred to technical competences (e.g. *Performance measurement*, *Planning*, *Variance analysis*), from the third edition there has been a shift mostly to soft skills, and this tendency has been confirmed by the following editions. Furthermore, with the sixth edition there has been not only a continuation of this trend, but also a revival of technical skills (e.g. *Data analysis*, *Data gathering*, *Estimating*), proving that with the sixth edition there is an on-going tendency in recovering some key issues emerged in the first editions of PMBoK, even if under a different awareness and perspective.

To answer the first Research Question, we can say that just like the evolution of KAs' and processes' centrality shed light on the evolution of concepts and views throughout the years, the study of Tools and Techniques provided new insights on the evolution of best practices. While, on the one hand, dynamics and changes among KAs and processes showed a rising and constant interest in issues like *Procurement Management* and *Integration Management*, on the other hand the evolution of best practices showed a movement toward soft skills.

Above all these considerations, the KA of *Project Risk Management* maintained a central role in all editions (second and third Research Question), proving that a constant attention has been always dedicated to this topic that keeps a central role in influencing the overall effectiveness and efficiency of PM discipline. Furthermore, the same can be stated for a few tools and practices, i.e. *Expert judgment*, *Meetings*, and *Project Management Information System*, which always maintained a central role, gained even more importance through the years (second and third Research Question). This last result confirm also the tendency, previously highlighted, that starting from the third edition brought a non-negligible interest in soft skills and their contribution to the success of PM, gaining a growing relevance (first Research Question).

Nonetheless, we must acknowledge that main the limitation of the study comes from its dependence from the standard book published by the Project Management Institute; this gave us a thorough view on the PM theory and its evolution, but there also other sources of knowledge on PM that should be taken into account for future researches and refinement of this study.

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