Chapter 2
Limits of Traditional Project Management Approaches When Facing Complexity

2.1 Project Complexity

Complexity is everywhere and is continuously growing in project environments. As stated by He and co-workers, "project complexity management which plays a key role in achieving the success of the complex project management has been an important part of project management" (He et al. 2012). It is all the more important since "complexity of projects is hotly debated and a factor which affects innovativeness of team performance" (Oeij et al. 2012).

There are historically two main scientific approaches of complexity (Schlindwein and Ison 2005). The first one, usually known as the field of descriptive complexity, considers complexity as an intrinsic property of a project system. This vision incited researchers to try to describe project complexity through factors and drivers, and to try to quantify or measure project complexity. For instance, Baccarini considers project complexity through the concepts of technological and organizational complexity. He regards them as the core components of project complexity which he tries to describe exhaustively (Baccarini 1996).

The other one, usually known as the field of perceived complexity, considers complexity as subjective, meaning that the complexity of a project system is always improperly understood through the perception of an observer.

Both approaches can in the end coexist since constructed frameworks for project complexity analysis are models of the reality of complex projects, and thus cannot encompass all the effects of complexity. Indeed, for all practical purposes, a project manager deals with perceived complexity as he cannot understand and deal with the whole reality of the project complexity, and its potential dramatic consequences.

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2.1.1 The Lack of Consensus on Project Complexity

There is actually a lack of consensus on what project complexity is. As Sinha and co-workers state it, “there is no single concept of complexity that can adequately capture our intuitive notion of what the word ought to mean” (Sinha et al. 2001). However, Edmonds proposes an overview of the concept of complexity within different fields and finally tries to give a generic definition of what complexity is: “Complexity is that property of a model which makes it difficult to formulate its overall behavior in a given language, even when given reasonably complete information about its atomic components and their inter-relations” (Edmonds 1999). This definition, which is quite appropriate to encompass all the aspects of project complexity, emphasizes that complexity is generally related to the way the project system is modeled. Later in this chapter, a definition of project complexity will be proposed in accordance with this definition.

Other attempts to describe and define complexity exist in the literature. We will cite some of the most noteworthy hereinafter. Karsky considers complexity as a three-component characteristic of systems (Karsky 1997):

- The first one, spatial complexity, is the structural complexity of a system, in terms of number and variety of elements and their mutual interrelations.
- The second one, unpredictable complexity, refers to chaos, fluctuations, and bifurcations, considering that the behavior of a system is in essence unpredictable since it is characterized by nonlinearity, as emphasized by Prigogine (1996).
- Finally, the third one, dynamic complexity, considers the presence of interrelations and positive or negative feedback loops, which makes it all the more difficult to understand the evolution of a complex system.

These three kinds of complexity exist simultaneously in projects. Spatial complexity is created by the number and variety of project resources, actors, tasks, processes, etc… This can notably be partially handled through simple models, such as the work breakdown structure which permits to define and group a project’s deliverables and tasks in order to help defining project scope. Unpredictable complexity is notably due to the fact that a project is an organization including people: by their actions, decisions and behaviors, they involve nontrivial nonlinearity within the project system. Finally, dynamic complexity can be underlined when building up project task networks which show evidence of interrelations and loops (tools such as the Design Structure Matrix—DSM can be used and will be presented later in this book).

As for him, Genelot considers complexity as one of the greatest stakes of today’s management, and thinks it should be understood at three different levels (Genelot 2001):

- The first level, real complexity, consists of internal characteristics of a system.
- The second level, perceived complexity, consists of one’s representation and model of the system.

- The third level is the feedback on the real system of the actions decided thanks to the system's representation.

Genelot defines a complex phenomenon as a phenomenon that cannot be totally understood and kept under control, emphasizing that complexity manifests itself at the three above-cited levels. In the end, he insists on the fact that anyone should keep in mind that being complex is in essence different from being complicated, and that confusion must be avoided between these two different notions: a complicated phenomenon can always be understood and kept under control through the work of experts and the efficient use of lessons learned and more or less advanced computational tools. Similarly, Ulrich and Probst also insist on the difference between the terms complicated and complex, categorizing systems in four groups in terms of structural complexity (Ulrich and Probst 1988): simple systems, complicated systems, complex systems, and very complex systems (see Fig. 2.1). According to this classification, projects are to be considered as very complex systems since they are composed of a large number of diverse elements which are nontrivially interrelated.

Complexity can also be considered as the property of a system that causes on one hand the emergence of new properties which none of the system elements owns, and on the other hand the apparition of phenomena which could not have been predicted with the sole knowing, even complete, of the behavior and interactions of the elements of the system (Marle and Bocquet 2001). Another interesting point from their works is that complexity can have both a negative influence (in terms of difficulty to be understood or controlled) and a positive one on the

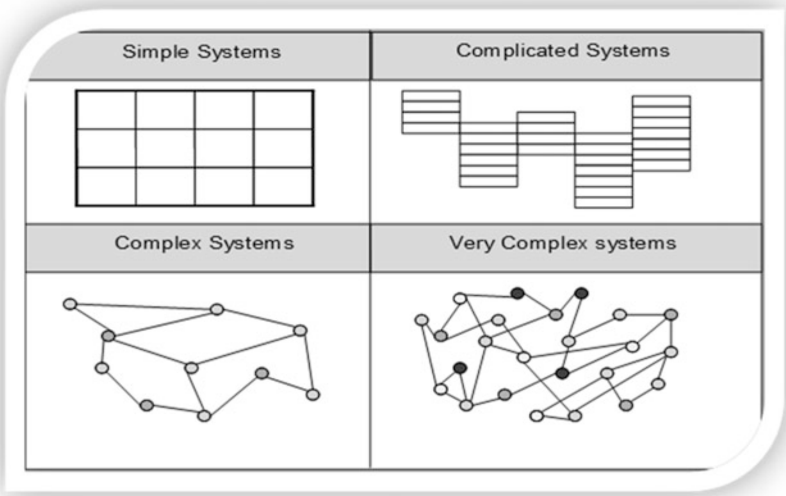

Fig. 2.1 The structural differences between systems—adapted from Ulrich and Probst (1988)

evolutions of project system (through the emergence of opportunities). Some researchers have therefore tried to define an optimally complex situation but we do not give details about these works in this book, since the most robust ones in the literature tend to be very specific to some project contexts.

Whatever the approach, whatever the school, some work has to be done to clarify the notion of project complexity in order to cope with it more efficiently (Vidal et al. 2007). However, this book proposes to keep an extension of Edmonds's definition to define project complexity, as in (Vidal 2009):

Definition
Project complexity is the property of a project which makes it difficult to understand, foresee, and keep under control its overall behavior, even when given reasonably complete information about the project system.

2.1.2 Impacts of Complexity on Projects: Project Complexity-Induced Phenomena

The links between project complexity and project performance are still unclear in the academic world as well as in the industrial one. For instance, Parsons-Hann and Liu state that "it is clear that requirements complexity contributes to project failure in organizations, what is not apparent is to what degree this statement holds true" (Parsons-Hann and Liu 2005).

This section illustrates how project complexity can be a source of different phenomena (Pich et al. 2002; Little 2005; Brady and Davies 2014; Svejvig and Andersen 2014; Yang et al. 2014). Four project complexity-induced phenomena are presented here: ambiguity, uncertainty, propagation, chaos. The overall relationship between these four concepts can notably be understood with models like the one presented in Fig. 2.2 and developed in the forthcoming subsections.

Let a project manager analyze a project system at a given time T in order to plan his decisions and actions for the next period to reach a state at time $T + 1$. The project system can be described by its real state at time T, a state the real complexity of which can also be considered at time T.

2.1.2.1 Project Ambiguity

When analyzing and monitoring the project system at time T, the project manager first perceives the real state at time T, introducing a difference between the real project state at time T and the perceived project state at time T ($\Delta_1(T)$). This

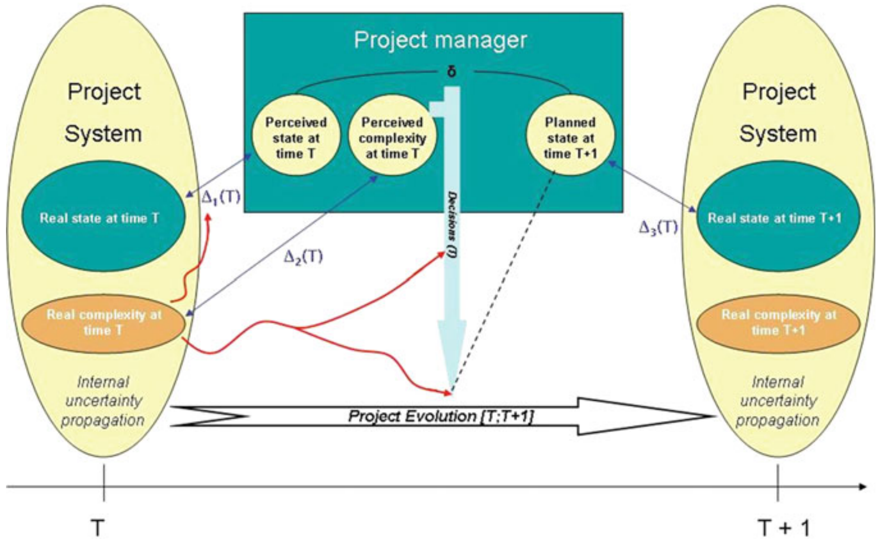

Fig. 2.2 Handling project complexity and uncertainty over time

difference has two principal causes. On one hand, the project manager has its own culture and references, and thus, his perception of the project system alters reality. On the other hand, real project complexity implies that the project system cannot in essence be completely understood. Indeed, there is always an irreducible residual source of non-exactitude caused by complexity when trying to identify the project system state (Thomas and Mengel 2008). This is mainly due to the high number and variety of elements and interactions that cannot be completely neither identified nor understood. For similar reasons, there is a difference, and thus another source of non-exactitude $\Delta_2(T)$, between perceived project complexity at time T and real project complexity at time T.

This question of perception has been approached by Jaafari (2001, 2003), and appears to be a crucial issue for project complexity. Jaafari insists on the fact that individuals, depending on their mental models and representations, perceive the outside reality in their own way. As a consequence, project complexity is dealt with through a filter. This filter is the individual perception of the project system and environment, based on one's representations. This is all the more true since the used semantics may be different from a project team member to another. In other terms, the difficulty is that the gaps $\Delta_1(T)$ and $\Delta_2(T)$ are different for any project team member, as anyone has its own perception of reality. These two phenomena, which are direct consequences of project complexity, can be grouped under the sole name of project ambiguity. Referring to some major works (Van Marrewijk et al. 2008; Pich et al. 2002; Jaafari 2003; Thomas and Mengel 2008), a definition of project ambiguity is proposed hereunder:

Definition
Project ambiguity is a project characteristic which encompasses two phenomena:

- The lack of awareness of elements, events and their characteristics (due to the overall lack of understandability of the project system), particularly when evaluating them.
- The differences in the perception of the project system by team members, notably because of their different cultures.

The leadership and flexibility of a project manager are therefore crucial skills so that a common reference and perception of reality can be shared within the project team, in order to reduce project ambiguity. Models describing project complexity or project characteristics when facing complexity can be developed to assist project managers. Some of them will be presented in Chaps. 3 and 4.

2.1.2.2 Project Uncertainty

Let us now have an overall look at the global process of project management. The project manager analyses the state of the project at a given time T and considers the difference δ between this state at time T and the state he planned for the next period at time $T + 1$. Then, the project manager makes decisions under constraints of project context and perceived complexity, and does corresponding actions to influence the evolution of the project to reach the planned state at time $T + 1$. This process is also altered by complexity-driven phenomena in terms of uncertainties (Martelli 2014).

First, decisions can be directly altered by real project complexity (Vidal 2009). For instance, the transmission of the information on a decision can be altered because of cultural variety, staff diversity, and staff interdependences: as a matter of fact, when turning this decision into an action, the actual action can be different from the action the project manager wanted.

Moreover, real complexity has an influence on the impact of the decisions made and the subsequent actions done (Lessard et al. 2014). The project manager deals with perceived (and not real) project complexity when making its decisions and moreover, real project complexity entails the project manager's inability or poor ability to forecast efficiently both the impact of its decisions and the project evolution (Ramasesh and Browning 2014), even though projections (notably in terms of time and cost) are performed (Acebes et al. 2014). Because of these those two reasons, real project complexity is one of the causes of the difference between the planned state at time $T + 1$ and the real state at time $T + 1$, introducing another difference $\Delta_3(T)$. This difference calls for project uncertainty, which makes it a direct consequence of project complexity (Pitsis et al. 2014). Project uncertainty will thus be referred to in all the next Chapters of the book, notably through sensitivity analyses which permit to study the robustness of a decision under uncertain contexts.

Definition
Project uncertainty corresponds to the inability to pre-evaluate project objectives and characteristics of the project elements as well as the impact of actions and decisions.

2.1.2.3 Project Propagation

Finally, project complexity is also a direct source of propagation within the project networks. Indeed, let an uncertain parameter P be in the project system, meaning that the value of P is known under conditions of uncertainty $P \pm \delta P$ (confidence interval). P can be for instance the duration of a task, the cost of a deliverable, or any dimension of any object of the project system. Since the project system is complex, it includes interdependencies and interconnectivities between its elements (tasks, resources…). As a consequence, the corresponding uncertainty δP on a parameter P can spread through the entire system, as any element in relation with parameter P faces uncertainty and transmits to all its neighbors in the same manner (Vidal 2009). Similar propagation can be faced with dealing with project risks (the impact of which is generally a delta in one or more project characteristics), and will be one of the main issues addressed in Chap. 5.

As underlined in Heylighen et al. (2006), "as technological and economic advances make production, transport and communication ever more efficient, we interact with ever more people, organizations, systems and objects." In the case of project management, one of the main consequences is that any change in any component in the project system may affect any other component of the project system in an unpredictable way because of change propagation.

Propagation phenomena are all the more complex to manage since a project, as any complex system, has a high number of various elements and interactions. This means, for example that uncertainty on the duration of a task T_i can be transmitted in terms of uncertainty on the duration of a task T_j, which can be transmitted in terms of uncertainty on the cost of a deliverable D, which can then be transmitted in terms of uncertainty on the quality of the global project outcome… In other terms, propagation in the project system is even more complex since the project manager has potentially to manage a change of nature, of magnitude or of ownership, at each stage of the propagation. The reader should particularly note that ambiguities and uncertainties should therefore be analyzed regarding propagation phenomena. For instance, one should deal with the uncertainty on a project characteristic, and study it also in terms of its consequences after propagating through the project networks (Ahern et al. 2013).

2.1.2.4 Project Chaos

Chaos and turbulence phenomena may appear during a project due to complexity. Chaos refers to a situation where short-term developments cannot be accurately predicted, notably because of the joint impact of interdependence and variability which were identified as complexity drivers (Tavistock Institute 1966). Chaotic phenomena are sometimes hard to separate from ambiguity, uncertainty, and propagation phenomena. However, they particularly correspond to a sensitive dependence on initial conditions. In this book, the authors do not develop these aspects of chaos and turbulence. However, the interested reader may find particularly appropriate concepts and references in (Dooley and Van de Ven 1999; Morel and Ramanujam 1999; Biggiero 2001; Snowden 2002; Bertelsen et al. 2003; Runolfsson 2005; Pich et al. 2002).

2.2 Limits of Traditional Project Management Approaches and Tools Regarding Complexity-Induced Issues

Consequences of project complexity presented in the former section are conditions which constrain the theoretical application of all traditional project management approaches presented in Chap. 1, since their application is theoretically under nonambiguous and non-uncertain contexts (exact numerical values for instance), and do not take any of this complexity-induced phenomena into account. This section permits to go through most of the traditional project management processes and tools introduced in Chap. 1 and present their limits in complex environments, regarding these complexity-induced phenomena.

2.2.1 Limits When Initiating Complex Projects

2.2.1.1 Limits When Specifying Project Values, Objectives, and Deliverables in Complex Environments

The approach for specifying project values, objectives, and deliverables which was presented in Chap. 1 is based on a holistic systems thinking approach, which is among the best to handle complexity.

Ambiguity Even though such systems thinking-based approaches encourages to have an overall vision of the project and its context (Sterman 2000), and to understand the different perceptions and interconnections which might exist, ambiguity makes it impossible to identify exhaustively and precisely each stakeholder (Bourne and Walker 2005; Jepsen and Eskerod 2009; Yang and Yeh 2013).

This is notably the case when different entities within the same stakeholder coexist and expect different things from the project. A direct consequence of this lack in identifying stakeholders and formulating clearly what they expect from the project (Liu et al. 2006) is that it makes it all the more difficult to specify exhaustively and define precisely each value, objective, and deliverable.

Uncertainty As stated in (Howell et al. 1993), "significant uncertainty exists at the start of most of the projects" within project organizations. No framework permits to handle this uncertainty, and notably uncertain objectives. Moreover, stakeholders are sometimes themselves not certain of their expectations of the project (Liu et al. 2006). This makes it all the more difficult to specify the context and objectives of the project.

Propagation In terms of propagation, due to the complexity of the network of stakeholders, objectives, and deliverables are often interrelated in a complex way. This makes it difficult to understand their relationships, even though multi-criteria approaches taking into account interdependencies (like the Analytic Network Process) have sometimes been used (Tsai and Chou 2009; Huang 2011). Similarly, the potential value creation of a project (for its different values) is difficult to assess, even though some multi-criteria methodologies have been developed to evaluate complex project proposals (Thamhain 2013) and decide whether to launch a project or not.

Chaos With chaos considered as the sensitivity to initial conditions, chaotic effects do affect the specification of project values, objectives, and deliverables, since "for most projects, the DNA of success is highly complex, and outcomes are difficult to predict, especially long term" given the variety of possible trajectories and scenarios of a given project with given initial conditions (Thamhain 2013).

2.2.1.2 Limits When Contracting Complex Projects

The relationship to the contracting process and project complexity is itself complex. Indeed, on one hand, contracts are notably used to control and contain complexity through an extended definition of terms and conditions, including the anticipation of possible scenarios. And on the other hand, contracts have often been pointed as an important source of complexity (Kapsali et al. 2013).

Ambiguity When organizations have gained experience with their contractors and partners, with former project or deals, the ambiguity of the contracts, even though complex, might be reduced due to a learning effect (Furlotti 2007). However, Banerjee and Duflo argued that the learning process over projects is quite little and that contracts often remain ambiguous, due to the fact that the new deliverables tend to be "complex and difficult to describe ahead of time" (Banerjee and Duflo 2009). Limits then appear: such ambiguity when defining contracts leads to their incompleteness, which makes them difficult to write, and more complex to refer to later on. But many researchers have also claimed that such incompleteness is not necessary a problem. Indeed, "such incompleteness is often an essential feature of a well-designed contract. Specifically, once some aspects of performance are unverifiable, it is often optimal to leave other verifiable aspects of performance unspecified" (Bernheim and Whinston 1998). Introducing ambiguity in a project contract can therefore also be seen as an opportunity to increase its adaptability. Indeed, a broad specification of requirements which does not restrict parties to imposed actions might introduce more flexibility for all stakeholders (Walker and Pryke 2011). A certain optimal level of ambiguity should thus be targeted, depending on each project context.

Uncertainty Uncertainty directly has an influence on the project contracting process. Two important limitations on the contracting process have widely been underlined. First, contracts might be incorrectly designed due to a bad anticipation of future uncertainties in the project (a contractor might delay its delivery after uncertainties play out). Second, if many uncertainties are pointed out, the negotiation processes with the contractors might be more complex since contractors might want to protect themselves more with larger guarantees (De Marco 2011), thus making it difficult to define appropriate terms and conditions of the contracts. The interested reader should refer to more advanced techniques based on incentives and their appropriate evaluation in order to navigate in such contexts (Back et al. 2013). However, to our knowledge, few works have been conducted to study deeply the influence of such uncertainty on the definition of the specifications of project contracts and the choice of a global project contractual strategy. This issue should however be addressed, since "the inherent uncertainty of the project (which should be correlated with estimated project size, the complexity of the project, the degree to which the firm and the client are familiar with the project, etc.) should also influence the choice of contract" (Banerjee and Duflo 2009).

Propagation In terms of propagation, the terms and conditions of a given project contract are often intertwined (Morris 1983), which makes it more complex to undergo the contracting process, since several terms and conditions are likely to influence each other. Due to the complexity of such projects, different subcontracts might be interconnected, which may directly influence the contracting process. For instance, a specific contractor might want to reduce the uncertainty on a given subcontract with a harsher negotiation on another subcontract. The conjoint negotiation of all subcontracts is thus necessary but to our knowledge, still very few approaches permit to define properly such complex contractual strategy. For more detail about innovative approaches for contracting in complex projects given the interdependence of stakeholders and their interests, the reader should notably refer to cooperation-driven techniques for contracting, such as (Margerum 2001; (Kees) Berends 2006).

Chaos To our knowledge, there is no contracting process or methodology addressing chaotic effects during the contracting process. This process being itself a subproject, it is itself complex, thus chaotic and sensitive to initial conditions.

Moreover, no methodology seems to include the anticipation of the unpredictable sensitivity to the initial conditions of the project. If such approaches have not been developed yet, we insist on the crucial role and skills of project managers in the way they anticipate such effects. Indeed, as stated by Hill, “project managers and contracts managers assume a central role in dealing with and managing these unpredictable conditions as they occur. It is fair to assume that this is a major part of their role within a contracting organization” (Hill 1999).

2.2.2 Limits of Traditional Approaches When Planning Projects

2.2.2.1 Limits of Traditional Approaches When Defining Scope and Work in Complex Projects

Ambiguity The issue of semantics and ambiguity when defining scope, decomposing work, and formulating activities was raised by several industrials and researchers (Winter et al. 2006). Apart from advices to use as precise formulations as possible when describing activities, like avoiding the use of the verb DO (PMI 2013), some work yet to be conducted to understand better the implications of ambiguity in the understanding of the formulations of WBSs and how to deal with it.

Uncertainty Building up tools like the WBS is a difficult matter in uncertain environments since a single change can completely challenge such hierarchical decomposition of scope and work. To the best of our knowledge, no recognized methodology permits to define uncertain scope or WBSs, even though such research perspective is promising to increase flexibility of project organizations (Söderlund 2002).

Propagation When coming to the description of the scope and work of a project and decomposing into processes and activities like in a WBS, “the interdependencies between activities can become so complex that meaningful networks cannot be constructed” (Hall 2012).

2.2.2.2 Limits of Traditional Approaches When Scheduling Complex Projects

Uncertainty The majority of research into project planning has focused on static project scheduling with deterministic parameters, which resulted in deterministic schedules, without taking into account uncertainty in complex projects (Brucker et al. 1999). Gantt charts and project scheduling networks are more adapted to static environments, with low levels of uncertainty (Maylor 1996). In such uncertain environments, approaches like the PERT, which require potentially biasing assumptions (Schonberger 1981) should be used with some caution, knowing that uncertain duration evaluations might directly influence the results and overall structure of project scheduling networks.

Calculations in project scheduling networks, and the consequent identification of critical path, generally use single time estimates for each activity and are thus uneasy to perform in uncertain environments (Hulett 1995). More advanced scheduling methodologies like robust and reactive project scheduling (Herroelen and Leus 2004), stochastic scheduling (Fernandez 1995; Ke and Shengze 2005) or dynamic scheduling (El Sakkout and Wallace 2000; Hicks et al. 2007) permit to handle part of project uncertainty in the project scheduling process but often remain too complex for industrial practitioners. In the end, whatever the method used, even though advanced, "in an uncertain environment […], plans are subject to many changes and are bound to be at least partially inaccurate" (Eckert and Clarkson 2010).

Propagation In terms of scheduling, complex projects with many interacting activities, with many possibilities of delay propagation over the project network, are undoubtedly difficult to plot on a Gantt chart for instance (Maylor 1996). In particular, they are often considered as very difficult to update in complex environments with many changes, because of the interconnection of activities.

Chaos Delay propagation may be nonlinear, with strong amplification phenomena. For instance, an activity has several successors and is late. If resources assigned to the successors are not available until a next period which is far later than the initial delay of the start date, then the final delay may be far higher than those of the initial activity.

2.2.2.3 Limits of Traditional Approaches When Planning Resource and Cost in Complex Projects

Ambiguity First, the resource allocation process is even more complex when information about the required skills or the skills possessed by potential project team members are unclear or ambiguous (White 1999). Moreover, role conflict and role ambiguity have a direct influence on the creativity of a project team (Kabiri et al. 2012). When project team members face unclear or ambiguous specifications of what they are meant to do, this makes it all the more difficult to execute and coordinate the project.

Uncertainty The inherent uncertainty of cost estimates makes it all the more difficult to establish a robust project cost baseline (Hall 2012). Even though some advanced methods try to build up cost envelopes for each part of a single project, they remain not widely used by industrial practitioners.

Propagation In terms of resource allocation, "a resource is a relative concept, rather than an element in itself (Håkansson and Waluszewski 1999) because it is heterogeneous and interdependent with other resources it is combined with"

(Vaaland 2002). Resource allocation approaches, however do not generally use this interdependence as a parameter, which may not facilitate resource coordination in the end (Söderlund 2002). Moreover, to the best of our knowledge, there is no reputed approach which directly introduces the interconnection of activities in terms of cost and the potential propagation and consequences of a possible overcost during the execution of the project (Vaaland 2002). One could however anticipate more the possibilities of cost reduction of other activities if a specific activity faces overcost. An interesting research perspective would be to facilitate the anticipation of cost monitoring and control through the introduction of possible cost decisions due to the complexity of the project networks.

2.2.2.4 Limits of Traditional Approaches When Planning Quality and Performance in Complex Projects

Ambiguity and Uncertainty The ambiguity and uncertainty of the specifications of stakeholders, values, objectives, and deliverables directly drives the ambiguity of project quality planning. There is evidence that complex projects and their performance "would be better managed by the application of systems thinking" (White 1999) but still very few project quality and performance management approaches are based on it.

Propagation Many authors claim for a better integration of planning of various project parameters, as well as their interdependencies, in order to plan better project quality and performance (Turner et al. 2013). Indeed, the interconnection of performance parameters and success factors (Söderlund 2002) has not yet been widely studied, even though it should be anticipated in order to avoid chain reactions in project performance loss (for instance a loss of quality regarding one targeted parameters, which implies rework thus delay and overcost, …) (Winter et al. 2006).

2.2.2.5 Limits of Traditional Approaches When Planning Risks in Complex Projects

Limits appear at all levels of the project risk planning process.

Ambiguity When performing risk identification, issues related to project ambiguity do appear as complexity-driven lack of awareness is to decrease the performance of risk identification. First, exhaustiveness is definitely impossible to obtain. Ambiguity cannot permit exhaustiveness. Furthermore, the project context is likely to change, and new risks can occur although they were not identifiable when first identification took place. As a consequence, exhaustiveness is never warranted by any method, even though the identification can be facilitated by previous lessons learned.

Moreover, a first classification of risks is performed during the risk identification process. Classifying risks by nature, by causes, or by consequences, or by time location are valuable alternatives which are difficult to compare. The point is that project risks are in essence multi-criteria (Mustafa and Al-Bahar 1991; Gourc 2006; Marle 2009; Wang et al. 2015) since they are related to several factors, project values, etc… But traditional methodologies fail in underlining these aspects and one notably tends to classify risks according to traditional classifications (the ones just expressed before). Choosing between these alternatives depends on the structure of the organization and of the project, on the risk management policy in the organization and on the ownership of risks. The choice of one of them is all the more difficult to do since ambiguity implies different visions within the project team.

When coming to risk analysis, some limitations related to ambiguity do appear, notably the fact that the evaluation of gravity and probability is very likely to be ambiguous, depending on the evaluator or group of evaluators, even though scales are often built for all practical purposes. Indeed, gravity and probability appear to be subjective concepts as the one of project risk: cultural phenomena, number of former experiences for instance have a major influence on the results of the risk analysis process (Gourc 2006; Marle 2009).

Uncertainty Uncertainty is also present during the risk planning process, and notably in the risk analysis process. The evaluation of these two parameters is in essence uncertain, even though it is done through expert judgment or using lessons learned or data of former projects. Some advanced methods permit to introduce some uncertainty aspects in the risk analysis process: methods based on fuzzy logic (Tah and Carr 2000; Zeng et al. 2007), or methods based on real options (Huchzermeier and Loch 2015) are useful, but often remain too complex for most of industrial practitioners. There are still few approaches dealing with uncertainty analysis in risk assessment.

Moreover, the last step of the risk planning process (risk response planning) also has lacks in terms of complexity-driven uncertainty. Uncertainty implies difficulty in the preparation of the preventive and curative plans. Uncertainty implies actions, which are themselves uncertain, and as a whole, "uncertainty will not necessarily diminish over time" (Jaafari 2001). Moreover, some actions may affect several risks, and some risks may require several actions, which makes it even more difficult to estimate the relative contribution of each action for each risk.

Propagation It is known that the risk classification method is likely to have an impact on the manner risks will be addressed among the other phases of the risk management process. In terms of propagation, the point is that whatever the classification chosen, the traditional ways of grouping risks (even by criticality values) does not permit to handle properly project complexity as shown by Fig. 2.3 next page. Risks are indeed mainly considered and identified as independent. But, for projects are complex, the project risks set are also complex since projects risks are interrelated too. Chain reactions and the domino effect are notably possible effects of complexity, due to propagation phenomena. To the best of our knowledge, no

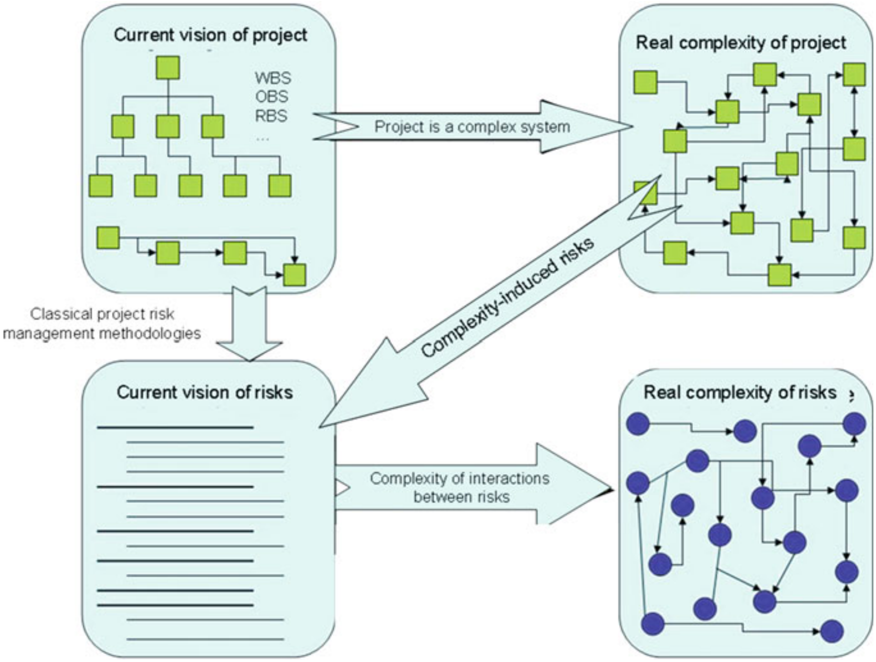

Fig. 2.3 Project risks under complex environments

traditional methodology has been widely implemented and used to identify these phenomena, even though sometimes secondary risks (indirect consequences of initial risks, since consequences of the implementation of actions to control the initial risks) are taken into account.

This is also the point when trying to analyze risks and propagation phenomena. As far as we know, no traditional method can permit a global analysis of the risk propagation phenomena, even though these phenomena may dramatically alter the obtained rankings. Indeed, traditional analysis processes "ignore potentially relevant information about the spread of possible impacts" for instance (Ward 1999). For all practical purposes, in the end, some risks that are traditionally neglected by current methodologies (because for instance, they have a very low impact) should not be neglected since they may be the root origin of more critical risks.

Some existing methods, such as Bayesian networks (Ben-Gal 2007), permit to underline to some extent propagation phenomena when performing a risk analysis. However, they do not permit to take into account feedback loops as one of the strong hypotheses of Bayesian networks is to work on directed acyclic graphs. Other methodologies such as Markov processes (Zhang 2009) can permit to handle part of propagation phenomena. But such methods may appear as non-intuitive and nonuser-friendly for industrial practitioners. Moreover, they do not permit a practical implementation of management modes which would handle risks in terms of their interactions. Finally, such methods are to be taken with caution, due to difficulty to manipulate the theoretical concept of probability when dealing with project risks, since references to the past are harder to do (Gourc 2006) and conceptual limitations do exist, as underlined in (Pender 2001).

2.2.3 Limits of Traditional Approaches When Carrying Out Complex Projects

2.2.3.1 Limits of Traditional Approaches When Monitoring and Controlling Complex Projects

Ambiguity Ambiguity implies difficulty when carrying out the project risk monitoring and control step (for the same reasons as in the risk identification step), making the process also subjective. In the end, project systems try to reduce subjectivity by expressing, monitoring and controlling the impact of risks on few limited scales (and especially the financial one). This does not permit to encompass the multi-criteria nature of project risks (Gourc 2006). Even though people and organizations tend to be more and more risk averse, risk management methodologies are still not so efficiently and effectively implemented, notably because of ambiguity and the lack of implication of management teams. Risk management is still too often considered as a waste of time and money, since working on potential events does not permit to see directly the practical effects of such a work. And as a whole, even though "the need for project risk management has been widely recognized" (Williams 1996), there is still some difficulty when trying to implement it properly in fieldwork.

Uncertainty When monitoring and controlling projects, traditional approaches like Earned Value Management do not take into account project uncertainty and variability, since they use deterministic values. However, a few extensions of such methods were developed. We notably recommend the cost control index and the schedule control index developed by Pajares and López-Paredes (2011) which permit to "integrate project uncertainty in terms of its parameters variability within the EVM framework to improve project control." Unfortunately, such approaches remain not that much widespread, since too complex for most of industrial practitioners.

In terms of project schedule monitoring and control, decisions are sometimes difficult to make and control due to project complexity-driven uncertainty. For instance, "crashing decisions become much more complex […] when task times are uncertain," notably since "uncertain task times may be correlated" in complex environments (Hall 2012).

Propagation When executing a project, very few approaches permit to facilitate the coordination of project organizations, and notably the interconnection of actors and activities. Actors do not generally realize that their decisions might have dramatic consequences on actors who are in their direct or indirect environment (Vidal 2009).

Finally, in terms of monitoring and control and notably the use of earned value methods, "a related weakness is that Earned Value Analysis assumes that tasks are independent, whereas in practice they are often dependent, and consequently variance in one task affects the performance of another" (Hall 2012). Similarly, risk monitoring and control is often not robust in terms of possible propagation since, the decision on a risk is itself risky and is generally not assessed in terms of possible consequences on other risks (Marle 2002).

Chaos Chaos mostly influences the efficiency of the project response plans and decisions, whether addressing risks, schedules, etc. Indeed, for instance, if some errors are made in the analysis and planning processes, it may have dramatic consequences during the decision process. For instance, the sensitive dependence on initial conditions implies that even little differences in the decisions made during the risk response planning step may imply important difficulties (Quinn 1985; Kiel 1995; Smith 2003). Other approaches even claim to change of paradigm and manage project by paradoxes (Riis and Pedersen 2003).

2.2.3.2 Limits of Traditional Approaches When Closing Projects

Ambiguity One of the limits of the redaction of lessons learned and their future use is the likelihood of ambiguity in their semantics. Future project team members might not be able to understand ambiguous terms in lessons learned files, especially, when people have left the organization, and part of its memory can be lost with them (March and Olsen 1976).

Chaos Lessons learned files are valuable tools, but in essence, not all projects will be the same, even though their initial conditions would be the same. This inherent chaotic aspect of project strongly lessens the direct application of lessons learned from past project, and proves that they should be used with great caution (White 1999).

2.3 The Next Chapters of the Book

After this significant but non-exhaustive introduction of project management traditional approaches and their limits regarding complexity, the structure of this book is built around two main parts:

- Part II is systems thinking oriented in order to propose new approaches to describe, measure, and manage project complexity and associated weaknesses.

The aim is to understand better complexity-driven phenomena and to be able to focus on the most complex and vulnerable parts of a project. Therefore, Part II mainly permits to reduce ambiguity and uncertainty related phenomena.

- Part III uses graph theory oriented in order to propose new approaches to model, analyze, and manage project elements and their interdependencies. The aim is to facilitate the prioritization of elements and the coordination of project actors under complex contexts. Therefore, Part III mainly permits to reduce propagation-and chaos-related phenomena.

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