AiIG

Associazione Italiana di Ingegneria Gestionale

XXIX RIUNIONE SCIENTIFICA ANNUALE

THE CHALLENGE OF MANAGEMENT ENGINEERING IN A CHANGING MANUFACTURING WORLD.
DEVELOPING COMPETENCES AND INTELLECTUAL CAPITAL ACROSS MANAGEMENT AND TECHNOLOGY

The dynamics around the shipyard: An organisational learning perspective for investigating project management complexity

De Toni A. F. (University of Udine)
Pessot E. (University of Udine)

11-12 Ottobre 2018
Castellanza (Italia)

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Alberto F. De Toni
University of Udine, Department Polytechnic of Engineering and Architecture
Via delle Scienze 206, 33100 Udine

Elena Pessot
University of Udine, Department Polytechnic of Engineering and Architecture
Via delle Scienze 206, 33100 Udine

Corresponding author:
Elena Pessot, elena.pessot@uniud.it

Keywords:
Project complexity; Learning process; Knowledge communities

1. Introduction

This research addresses one of the major topics under investigation in the recent project management literature, i.e. the complexity in projects and in project management, and how organisations are dealing with it. Project complexity can be defined as an inherent characteristic of a project that results from the interrelations and the dynamics among its many parts (Baccarini, 1996; Maylor and Turner, 2017). From the perspective of the people working in projects, it is something which is perceived or experienced, including both negative (difficult to understand, to foresee and to keep under control) and positive aspects (emergence) (Cooke-Davies et al., 2007; Vidal et al., 2011).

Complexity – and its growth at a faster rate than the capability to cope with (Maylor and Turner, 2017) – has been recognised as a major topic of discussion in project management research and practice. Dealing with the interdependency, uncertainty and change of contemporary projects and their dynamic environments poses new challenges (Cooke-Davies et al., 2007) and requires a more contingent approach in managing projects, beyond the conventional linear systems and the "Tayloristic one best-way approach" as a reference model to apply to any type of project or industry (Blindenbach-Driessen and van den Ende, 2010; Shenhar, 2001).

The appropriate approaches and managerial actions to understand and address the increasing complexity of projects are a key determinant for the success of organisations, especially the so-called Project-Based Organisations (PBOs), defined as a type of organising where projects are the primary units for coordinating and integrating production, organisation, innovation and competition (Davies and Brady, 2000; Bartsch et al., 2013). From the one side, teams such as the ones involved in single projects of an organisation are defined as the fundamental unit of learning and organisational effectiveness (Leonard-Barton, 1995; Nonaka and Takeuchi, 1995; Senge, 1990). From the other side, PBOs face specific challenges when capturing, sharing and embedding new knowledge and learning from projects at the overall organisation level (Davies and Brady, 2000; Bresnen et al., 2004). Beyond the growing complexity, main challenges are the decentralised organising of the teams, the interfaces between the temporary and permanent organisation (Stjerne and Svejenova, 2016) and the ways of working constrained by tight schedules and optimisation towards the achievement of the single project goals, resulting in distributed knowledge and working practices (Bresnen et al., 2004; Orlikowski, 2002). A consideration of the contextual conditions (e.g. level of complexity of the projects) for organisational learning and the processes of emergence is therefore required (Mitleton-Kelly and Ramalingam, 2011).

2. Theoretical background

2.1 Complexity in projects and project management

Complexity has been defined as an inherent characteristic of a project that results from the interrelations and the dynamics among its many parts (Baccarini, 1996; Xia and Chan, 2012). From the perspective of the people working in projects, it is something which is perceived or experienced, including both negative (difficult to understand, to foresee and to keep under control) and positive aspects (emergence) (Bosch-Rekveldt et al., 2011; Dawidson et al., 2004; Vidal et al., 2011), resulting from the dynamic changes in the environment, increased product complexity and project constraints (Williams, 1999). The concept of complexity has gained interest for several reasons. Firstly, complexity in projects has been recognised growing at a faster rate than the capability to cope with (Maylor and Turner, 2017). Secondly, it has been defined as one of the causes of risks (Vidal and Marle, 2008) and failure in delivering project outputs if underestimated or not properly managed (Brady and Davies, 2014; Bosch-Rekveldt et al., 2011; Williams, 1999). Thirdly, the application and mastering of complexity is a key to improving performance and consequently determining the appropriate managerial actions to complete a project successfully (Baccarini, 1996).

The growing number of studies on project complexity has lead to a lack of consensus on its conceptualization (Vidal et al., 2011) and effects on projects success or failure (Bosch-Rekveldt et al., 2011; Brady and Davies, 2014; Williams, 1999). For example, Tatikonda and Rosenthal (2000) suggest that projects with high levels of project complexity are not associated with overall project failure, but specifically the relative newness of a project's objectives to the firm. Nevertheless, we observe a substantial agreement on the presence of numerous elements within the project, the interactions and the interdependencies among them, and their variety. The most recent definitions identified (i.e. Bakhshi et al., 2016) show a more interest towards the dynamics and the emergence of features and effects. The effects have been interpreted mainly in terms of difficulty in managing the projects by the previous studies (e.g. Vidal and Marle, 2008; Vidal et al., 2011).

Moreover, the subject of complexity has been linked both to technical and socio-organisational aspects. The technological aspects mainly regard the product or service to be delivered (Tatikonda and Rosenthal, 2000). The non-technical aspects include the communication, the behavioural and social influences and interactions between people, organisations and the external environment (Bosch-Rekveldt et al., 2011; Geraldi et al., 2011). Integrating both aspects, Table 1 summarises the dimensions and the types of project complexity identified in the project-oriented literature, i.e. diversity, interdependency, dynamicity, uncertainty.

Table 1 – Dimensions of projects complexity in literature

			References							
Dimensions	**Definition**	**Concepts from literature**	Baccarini (1996)	Bakhshi et al (2016)	Brady and Davies (2014)	Geraldi et al. (2011)	Maylor et al. (2008)	Maylor and Turner (2017)	Shenhar (2001)	Williams (1999)
Diversity	Size, number, heterogeneity and variety of the elements and subunits of the project, including hierarchies	Differentiation	•							
		Diversity		•						
		Size		•						
		Number of …				•		•		
		Hierarchy			•		•			
		Scope							•	
		Variety								•
		Structural complexity				•		•		
Interdepen-dency	Degree and emergence of interactions and connections among the elements and subunits of the project	Interdependency	•			•		•		•
		Connectivity		•						
		Interactions								
		Belonging		•						
		Structural (relationships) complexity			•		•			•
Dynamicity	Pace, rate of delivery and change of the project; it includes the temporal aspects (speed)	Pace				•				
		Dynamics			•	•				
		Instability								•
		Changes					•			
Uncertainty	Linked to the unknowns, variables to predict and manageability of the project and the planning in terms of novelty, experience, and availability of information	Emergence		•						
		Ambiguity								
		Uncertainty				•				•
		Unpredictability			•					
		Structural (subsystems) uncertainty	•							
		Technological (novelty) uncertainty	•				•	•	•	

2.2 Organisational learning in project-based organisations

In PBOs the mainstream activities are entirely (or mostly) based on projects, usually for the design of bespoke solutions (Koskinen, 2012) and the production of one-off, unique products to fulfil the requirements of customers (DeFillippi and Arthur, 1998; Gann and Salter, 2000; Hobday, 2000).

Projects are widely recognised as being "arenas of knowledge formation and learning" (Ahern et al., 2014:1427) and then a source of innovation (Gann and Salter, 1998). Consequently, they should be framed as a learning process, requiring interdependency and frequent communication (Edmondson and Nembhard, 2009). Organisational learning, i.e. the learning process at organisational level (Huber, 1991), becomes a key strategic performance driver in the PBOs (Blindenbach-Driessen and van den Ende, 2006; Brady and Davies, 2004).

Much attention has been directed to conceptualise the ability of organisations to learn and then identify the most effective and efficient processes for achieving it (Huber, 1991; Senge, 1990). Learning takes place following knowledge creation and capture (for example through repositories), then the knowledge gained should be codified to be properly transferred to the overall organisation (Prencipe and Tell, 2001; Brady and Davies, 2004), e.g. in the development of new products. The overall process of learning in PBOs requires the subsequent selection, retention in knowledge repositories and reuse of the knowledge created in prior projects to generate new value (Bartsch et al., 2013; Keegan and Turner, 2001). Indeed, project-based learning takes place either within the same project (within or intra-project learning) or between one project and another, i.e. between or project-to-project learning (Ayas, 1997; Koskinen, 2012). Along with this line, learning is intended through or from projects (Brady and Davies, 2004).

Organisational learning from projects faces significant challenges due to the uniqueness, the one-off and constrained nature of projects and the distributed knowledge among project teams, which can hinder the codification and transfer of the newly created knowledge to the subsequent projects and the overall organisation (DeFillippi and Arthur, 1998; Edmondson and Nembhard, 2009; Keegan and Turner, 2001; Lundin and Söderholm, 1995; Prencipe and Tell, 2001). The temporary nature of project teams, the higher pressure towards the end of the project due to discontinuity at both temporal and organisational level, and the fundamental complexity of new products, have been recognised among the key issues that inhibit such learning (Williams, 2008). These elements lead to distributed knowledge and project practices among the several teams, with a difficulty into sharing and transferring the lessons learned to the overall organisation (Edmondson and Nembhard, 2009; Gann and Salter, 2000). The created

knowledge appears to be highly specific within the particular, multi-professional project team, resulting into the development of a decentralised practice and the less opportunities for routinized learning (Bresnen et al., 2004).

Focusing on the project-based learning, Table 2 summarises and defines the key process of organizational learning within the development and management of projects and the main constraints that challenge these processes.

Table 2 – Organisational learning and constraints in projects

ORGANISATIONAL LEARNING			**REFERENCES**
Processes	Experience accumulation	Experience-based learning, e.g. deriving form learning-by-doing and learning-by-using	Prencipe and Tell, 2001; Brady and Davies, 2004
	Knowledge acquisition	Process of extracting, structuring and organising knowledge from one or more sources, e.g. through imitation or replication	
	Knowledge codification	Cognitive process that implies deliberation and creation of agreed upon representation through, for example, codified manuals and procedures	
Project constraints		Short-term objectives vs. longer-term relationships; tight schedules, high quality requirements, budget; one-off and non-recurring nature of project activities; less opportunities for routinized learning	Ahern et al., 2014; Ayas, 1997; Brady and Davies, 2004; Bresnen et al., 2004; Lundin and Söderholm, 1995

3. Methodology

This work aims to investigate how organisations are facing the complexity of their projects based on the reflections and perspectives of the learning gained by the project management teams at the organisational level. We build on 1) the dimensions of project complexity identified in the project-oriented literature, i.e. diversity, interdependency, dynamicity, uncertainty, and 2) the key organisational processes of organisational learning in projects environments (Prencipe and Tell, 2001), i.e. knowledge creation through experience accumulation, knowledge acquisition (from other sources or contexts), knowledge codification in order to answer the following research question:

How do organisations face project management complexity within and across their projects from an organisational learning perspective?

Aiming for sense-making and increasing understanding of emerging features of complexity and organisational learning processes, this study applies a qualitative methodology (Biedenbach and Müller, 2011) and an exploratory approach (Yin, 2013). Moreover, there is the need to (1) take into account the institutions within which projects are embedded and interact, extending

the contingency-based approaches (Shenhar, 2001), and (2) study learning within projects as nested, or embedded, within the broader organisation level (Bresnen et al., 2004). Following these assumptions, we employed an embedded cases study design, with the main unit of analysis a PBO and the sub-units the ongoing projects – to better investigate the 'actual' complexity and organizational learning processes. We selected a large, leading company of the shipbuilding industry. The company is a cutting-edge and active player in all the high-tech and highest added-value sectors of the shipbuilding industry, and specifically the global leader in the construction of cruise ships. It has decades of experience in the technology, design and engineering of the overall ship's system in an integrated and flexible project model that oversees all stages of the cruise ships production, including design, supplier selection, construction, commissioning, testing and delivery. Throughout its historical evolution, the company has been able to implement new strategies and adapt its organisational model in order to retain long-term competitiveness and then successfully survive and growth, also during the worldwide crisis that impacted both the shipping and the shipbuilding industry. Overall, the company is leading all the knowledge domains judged as key for the organisational performance, i.e. knowledge about market conditions, about products and technologies, and project management (Bartsch et al., 2013). Moreover, the organisation shows a positive attitude towards further professionalisation of team members and fostering mechanisms and approaches for learning at the organisational level in front of the increasing complexity of its projects. Each ship is complex, custom-made and has to be designed to the unique requirements of the customer (Davies and Brady, 2000). The complexity of the products is reflected in the design and construction process, which involves several subsystems with different functions and numerous activities that have to be effectively coordinated and integrated by the project management teams. For each vessel project, the teams have to deal with a variety of (and often conflicting) interests of external stakeholders, from the wide network of heterogeneous suppliers and sub-contractors integrating the internally and externally developed components, to the customer deeply involved in possible changes to the ship design for the overall duration of product development process, to the requirements of the overall organization.

The contextual features of a PBO allowed to investigate the dimensions of project complexity (i.e. diversity, interdependence, dynamicity, uncertainty) and the patterns and mechanisms of organisational learning (processes, levels and the issues linked to project constraints) within projects embedded in a common organisational context. During the study, the project teams were employed in a total of 7 projects. The population of 7 projects shows complex multivariate conditions (Yin, 2013), with a variance on the criteria (Eisenhardt, 1989; Shenhar and Dvir,

1996): size of the ship, technological newness (sister ship if the platform is in common with a prototype), shipyard (production site), delivery date (therefore corresponding to different timings in the product development), customer (highlighting the distinctive features of ship layout and mainly impacting on the design). Table 3 provides evidence of the criteria.

Table 3 – Overview of the projects selected in the case study

PROJECT			**SHIP**		**CUSTOMER**
N.	**Shipyard**	**Delivery**	**Size**	**Type**	**Distinctive features**
1	A	Feb 2020	110 k gross tons	Prototype	New client, new entrant in cruise ship market
2	B	Mar 2018	134 k gross tons	2nd Sister	Historical client, long-term relationship, among key players in the market
3	B	Jun 2022	140 k gross tons	Prototype	Among the most innovative brands
4	C	Nov 2017	152 k gross tons	Prototype	New client, among key players in the market
5	C	Oct 2019	145 k gross tons	4th Sister	Historical client, long-term relationship and contract
6	A	Mar 2017	41 k gross tons	Prototype	Brand focuses on luxury and innovative design
7	B	Mar 2019	136 k gross tons	1st Sister, brand change	New market

The phase of data collection employed multiple sources to enable triangulation (Yin, 2013) and lasted for more than one year. The sources of evidence were interviews, field notes, qualitative questionnaires, documents and archives. Focusing on interviews, an interview guideline was developed ensure the coherence and the consistency and 12 informants (managerial roles such as project managers, purchasing coordinators and cost controllers) were involved in a total of 16 interviews (with 4 informants interviewed on 2 projects). The interview data were thus integrated with qualitative questionnaires administrated to members of the 7 teams, field notes from each interview and each meeting, documents and archives.

A database was prepared for each case, including primary and secondary sources, and data were analysed following a two-step procedure, involving a within-case analysis and a search for cross-case patterns (Eisenhardt, 1989; Voss et al., 2002) in terms of dimensions of project complexity and organisational learning processes.

5. Results

Results of the study highlight the main mechanisms carrying to specific sub-processes of learning – experience accumulation, knowledge acquisition and knowledge accumulation – when dealing with different complexity dimensions in the analysed projects. Table 4 summarises main elements, concepts and mechanisms of complexity and organisational learning within the selected projects. In the following, the results from the within- and cross-case analysis, highlighting dimensions and elements of complexity and organisational learning per each project and in the overall PBO, are presented and discussed.

Table 4 – Complexity and organisational learning in the selected projects

	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6	Project 7
COMPLEXITY DIMENSIONS							
Diversity	New professional roles and responsibilities Ship size	Ship size Number and type of subsystems to be reviewed Amount of different information	Professional profiles of team members Number of details to consider in the analysis of the key processes Elements to be considered to respond to brand's requirements	Ship layout and size Higher number of stakeholders due to higher amount of *owner supplies*	Ship size Redundancy of technical systems Differences in the two shipyards where the production take place Workload and shipyard occupation	Ship size (small) Higher level of customisation (variety of subsystems) Different informative tools for executive engineering	Ship layout Foreign shipyard Higher number of suppliers
Interdependency	Better interactions between design and production roles Interactions with the architects employed by the shipowner Alignment on project goals Shipyards capacity requirements	Platform in common with ships of the contract and other brands Frequent interfaces with the customer Outsourcing of the production of a section in a foreign shipyard Synergies with the team involved in the other sister ship Backlog of the design work from the prototype ship	Strong ties between team members Multiple interfaces with experts and other departments Linkages between process, organisation and tools Interfaces with design and purchases department	Reverse engineering Customer requirements result in more interfaces with the operations department Higher number of interfaces between subsystems (due to several supplies) Externalisation of part of the production to different shipyards	Substantial portion of engineering linked to the prototype ship Interfaces with the technical offices	Higher integration between ship subsystems Strict interfaces between planned phases Coordination with the redundant installations	Changed team Previous multi-client team Building of the sister ship already starting Need to foster information sharing

Dynamicity	Evolving team structure Innovative technologies (e.g. engine) introduced during implementation Flexible decision-making due to less customer expertise in cruise ships construction	Decision-making process with consolidated customer Change of project team members (technical) Change of the shipyard (with respect to the prototype) Changes required by the shipowner Reconfiguration of purchasing orders	Decision-making to anticipating critical activities Low-level, challenging objectives	High percentage of *owner supplies*	"Stratified" and articulated decision-making process Prominent level of change orders Pace of improvements Changes in the final market Innovations for the energy saving	Introduction of innovations for comfort and energy saving Prominent level of change orders and *owner supplies*	Final market dynamics Decision-making process Difficulties in the handover phase
Uncertainty	New customer, new entrant within the cruise market Creativity Prototype (technological newness)	New requirements from the change of the shipyard Ambiguity in managing the flux of information	First phases of functional design Introduction of innovation (technological and organisational)	New position of the customer within the portfolio with specific requirements Elements of novelty: ship design, customer, supplies, building process Ambiguity and need to prevent codes allocation	Historical but eclectic brand Economic issues when trying to lower prices	New design subcontractors within the network Cultural distances with the foreign shipyard and subcontractors New customer introducing not feasible requests Ambiguity in the definition of the standards	High level of outsourcing Grey zones, unknowns Absence of established procedures for information sharing with foreign shipyard New brand Cultural distance
ORGANIZATIONAL LEARNING PROCESSES							
Experience accumulation	Face-to-face communication within the team and with the customer	Economies of repetition for the platform layout Focused meeting to collect	Support in problem-solving Team climate enabling try-and-learn	Daily meetings with operations functions	Important contractual phase Technical elements	Procedures for project monitoring Activities for the detailed	Try and learn Focus on minor orders

	Training of the customer Shared awareness of the impacts of the changes on final delivery Trust mechanisms thanks to better and more frequent knowledge sharing	information needed	Awareness of impacts pf processes from deeper analyses	Informal exchanges with other teams Communication and decision-making process with the customer		implementation of the layout Side-to-side support to the customer Daily, side-to-side work with the shipyard	
Knowledge acquisition	Expertise of the technical referees now belonging to the team Introduction of innovative technologies for cruise ships from other products	Feedbacks from marketing and customer experience Inheritance from the prototype ship	Imitation of competitors Previous experiences from higher professional seniorities	Customer of the other business unit of Fincantieri Reengineering from a ship realised by a competitor Informative tools	Modularity in the workshop activities from the previous ship Main technical background	New ways of working for the functional design from the prototype ship Guidelines to be customised for the planning and control	Recovery from knowledge repositories Internal transfer of information already defined
Knowledge codification	Contractual programme as a base for the relationship with the stakeholders Systematic review of project plan in an innovative tool for changes monitoring	Guidelines for the shipyard Review of ship specific design sheets Management tools to trace the changes	Standard procedure for design phases in prototype ships Formalisation of best practices Systematic presentations of the innovative approaches	Capitalisation of the interventions on the production engineering Specific transactions on the enterprise resource planning system	Systematic tracking of meetings minutes Creation of a tool for the warnings	Systematisation of the interfaces with the shipyard personnel Contribution in the structuring of the professional career paths Contribution to development of the common informative tool for project planning	Formal project reviews Formalisation of functional interfaces
Project constraints	Awareness of the shipowner on	Higher quality requirements than the prototype ship	Shipyards priorities	New and specific requirements with	Long-term contract	Important level of quality (luxury segment)	Tracing impacts of minor purchasing orders

	construction constraints Saturation of shipyard capacity requires rigorousness in respecting the deadlines Efficacy thanks to interaction and alignment between roles	Binding of ship design specifications Knowledge transfer between different production sites	Time to introduce improvements Challenging lead times	impact on the quality Flexibility for owner supplies Multi production sites		Balance between qualitative standards and compliance with international rules Higher costs than budget due to the need for new subcontractors	

5.1 Complexity dimensions in cruise ship projects

Cruise ships projects are recognised as being complex mainly because of the high level of complexity of the product, the level of customisation that requires a dedicated project management process, a high number of stakeholders and the goals that the process itself has to achieve by following tight project constraints. These latter are strictly linked to the low marginality, as the design and production of a cruise ship require the supply of several components and subsystems (as turnkey projects) from a wide network of subcontractors, and prolonged periods (i.e. up to three years). Shipbuilding is indeed an engineer-to-order and not a mass production industry, and each shipyard has a prominent level of externalisation, requiring a proper coordination and integration of several actors. In the case study each project is managed by a team that is usually customer-oriented. It has a strong focus on the brand of the shipowner, aiming to ensure a long-term relationship with the customer through the same interfaces and approaches, and each project is linked to a contract (which discipline the delivery of more than one ship per customer). The prominent level of customisation and the high customer power result in the need to accept several change orders from the customers and coordinate a huge construction process with several constraints in terms of integration. Conversely, the interfaces of project management teams are manifold: they are required to deliver a ship on time, on budget and fulfilling quality requirements by dealing with the functions directly involved in the development and construction phases, involving several stakeholders with different objectives. Therefore, the organisational forms, the attitudes and the managerial and organisational practices put in place have several implications for the success of the project.

Focusing on single complexity dimensions, their levels and constituent elements, Project 2 and Project 6 show a higher overall complexity. The former is strongly conditioned by interdependency and dynamicity. It comprises the delivery of a sister ship, whose platform derives from the one of a prototype ship that was implemented with a lower price than expected. The team members are dealing with the backlog of design work inherited corresponding to the missing details of the previous project, where the implementation of the essential parts and not the tracing of the changes was privileged. Moreover, the project development was affected in terms of dynamicity by the change of some of the project management team members (specifically the technical experts), the need to accommodate several change orders from the shipowner, based on its and the customer experience – as it is one of the main players in the cruise ship market – and the main shipyard where the ship is built, with severe impacts on the overall decision-making process. As regards Project 6, the most relevant dimension is the

dynamicity, due to a higher attention towards the target quality (as it is a ship belonging to the luxury segment), the need to satisfy highest regulations in terms of complete functioning, energy savings and comfort, the prominent level of change orders and owner supplies (i.e. the purchases directly decided by the customer, especially in terms of unitary value per size of the ship). Furthermore, the other complexity dimensions play a significant role in determining the overall complexity level as well, in a connected way. Diversity is also linked to the level of customisation in terms of subsystems, interdependency as well results from the interconnections among these and the network of stakeholders. This influence prominently also uncertainty, as it derives from new design subcontractors within the network, cultural distances with the foreign shipyard and subcontractors, new customer introducing not feasible requests, ambiguity in the definition of the standards, resistance to change by the operational departments.

Generally, projects are characterised by higher levels of interdependency and dynamicity rather than uncertainty. This fact can be justified by the actual state of the projects, as they are all ongoing at the time of the study. Most of them is at distinct stages of the design, engineering and production phases. The dimension of interdependency, i.e. the degree and emergence of interactions and interconnections among the elements, is the highest on average. Despite each team deals with different customers, shipyards and in general stakeholders, they are all strongly connected and spend much efforts in integrating and coordinating a smaller or bigger network of relationships. Moreover, the product itself is made of subsystems that must be integrated and properly managed throughout the project lifecycle. For example, Project 4 is developing the reverse engineering from a ship designed by a competitor, therefore leveraging on the interconnections with the previous drawings, and is dealing with a high number of interfaces with several supplies and different shipyards to which the production was externalised. The team involved in Project 5 is having mostly interfaces with the technical offices, due to the significative technological content of the ship (e.g. redundancy of technical systems). This latter is present also in Project 6, but the main interconnections are between the planned phases and the ship subsystems, beyond the redundant installations as well. Finally, the dimension of interdependency in Project 7 is mainly in terms of interconnections between multi-teams, as it is strictly linked to the previous configuration of the team and to the building of the following sister ship, which is already starting at the time of the study.

Conversely, the dimension of diversity presents the lowest mean value among the seven projects. This is mainly due to the ship sizes and layouts, the composition of the teams, the use of different practices and tools supporting the project management process, the number and

type of information to be considered. All these elements represent a minor driver of complexity in terms of management of the related project as they mainly reflect the experience and the modus operandi of the overall company, which is mainly client-oriented and has a strong expertise in all these variables – a characteristic that is in common with all the projects within the current portfolio. Also the dimension of uncertainty is lower, and mainly due to the newness of the customer (e.g. Project 1 and 7), the newness of part of the stakeholders involved in the design (e.g. Project 6) and purchasing (e.g. Project 4) phases, the introduction of technical or organisational innovations (e.g. Project 1 and 3), the cultural distance (e.g. Project 6 and 7) and ambiguity in the information, the setting of the standards or the presence of unknowns (e.g. Project 2, 4, 6 and 7).

5.2 Organisational learning in cruise ship projects

Specific learning processes can occur often as an unintended outcome of the project activity (DeFillippi and Arthur 2002). The prevalence of complexity dimensions as key contextual variables under study might play a key role in determining the type of learning (Sorenson, 2003). Project 2 and Project 6 show the most relevant elements also for this variable. For what concerns Project 2, this is mainly due to the inheritance of the prototype ship, which resulted in both positive (e.g. commonalities and opportunities for economies of repetition and the feedbacks from the customer experience) and negative (e.g. backlog of the design work, the amount of changes required by the shipowner, the reconfiguration of the production in another shipyard and the purchasing orders) aspects. This resulted in the prevalence of knowledge acquisition, as the team leveraged the previous information and proactively created occasions to collect as many data as possible with focused meeting to collect the information needed from all the stakeholders. Moreover, basing on this lesson learned and the willingness to avoid the problems encountered in reviewing the previous project, the project management team is often codifying the knowledge acquired in new or improved tools. They are updating specific management tools to trace the changes, both from the purchases (e.g. variations in suppliers' deliveries) and the production (e.g. variations in the cost structures) point of view, with also the support of guidelines. These enable the interested parts in having a direct, real-time and complete information and is in charge of approving the following changes to its project. Differently from Project 2, in Project 6 the experience accumulation is prominent in the knowledge creation process: indeed, dealing with the high standards and subsequent requests of all the stakeholders involved, resulted in the emerging, from the bottom, of informal procedures for project monitoring, activities for the detailed implementation of the layout, a

side-to-side support to the customer and work with the shipyard. The knowledge gained in this way was then promptly systematised into better definition of the interfaces with the shipyard personnel and a twofold contribution in the structuring of the professional career paths and to the development of a common informative tool for project planning. Overall, we can say the main innovation and change management initiatives are mainly developed at the front-end stage. One of the main opportunities for innovation is the organisational redesign (Gann and Salter, 2000; Hobday, 2000), as in Project 1 and 3 with the strong matrix configuration.

Generally, projects are characterised by higher levels of knowledge acquisition and codification. This reveals a positive attitude towards building on the knowledge gained in other projects (e.g. Project 2 and 3), or in other teams (e.g. Project 7), or the information coming from and the competences of the project stakeholders, starting from the functional departments such as the shipyards (e.g. Project 5 and 6), to the customer itself (e.g. Project 2), to the competitors (e.g. Project 3 and 4). Moreover, several mechanisms have been put in place to codify the knowledge created into tools and practices to be shared in the next future with the other teams and the upcoming projects. The single project teams explore their space of possibilities and or alternative strategies to generate a variety of responses under different environmental conditions (Mitleton-Kelly and Ramalingam, 2011). Examples of mechanisms include innovative tools for changes (e.g. Project 2) and minor items (e.g. Project 7) tracing and monitoring (e.g. Project 1), the contribution to the development of the common informative tool (e.g. Project 6), for project planning guidelines for the production stages (e.g. Project 2), the creation of specific transactions on the enterprise resource planning system (e.g. Project 4) and a tool for the warnings (e.g. Project 5), the core contribution in the structuring of the professional career paths (e.g. Project 6) and the functional interfaces (e.g. Project 7).

An important result is that, on average, a higher level of both interdependency and dynamicity (even more if both present as in Project 2) results in a higher knowledge codification. Beyond the experience of the NPD teams, dealing with several interfaces (i.e. customers, functional units, design and production subcontractors) and pace of the projects allows for a better organisational learning process. Higher interdependency requires building on feedback loops and create brainstorming sessions to map the interconnections, reconsidering the challenges to be faced from other projects, as it has been done in Project 2, with a higher number of focused meetings with the experts for the definition of guidelines for the new shipyard and the overall project. Interaction is essential for learning to take place (Mitleton-Kelly and Ramalingam, 2011).

Focusing on the single dimensions, a higher diversity mainly results in the need to acquire knowledge from the external of the project. For example, in Project 4 the high level of innovativeness of the ship required to leverage on the re-engineering (and then the imitation) of the model previously delivered by a competitor, the knowledge from another business unit of the company and other teams as stocked in the common informative tools. The higher dynamicity requires both knowledge acquisition and codification. The acquisition comes mainly from strongly relying on the external sources, and in particular on the previous projects, the previous experiences of the team members and also the competences of the main stakeholders, when properly shared. Indeed, people working in projects use their existing knowledge to help guide their action, but gain understanding of the new type of project by carrying out their specific work in a socially constructed context (Winter et al., 2006). The codification mainly addresses issues that are specific of the ongoing project at the operational level, as it has been done in Project 6, with the main focus on the integration of the planning and programming with the functions due to the technological content. The tools and practices codified in each project should be then properly reviewed to be shared with the overall organisation.

6. Discussion

Table 5 summarises the main mechanisms carrying to specific sub-processes of learning when dealing with different complexity dimensions in the analysed projects, in an interpretative framework obtained from the cross-case analysis.

Table 5 – Complexity dimensions and organisational learning in projects

	ORGANISATIONAL LEARNING PROCESSES		
COMPLEXITY DIMENSIONS	EXPERIENCE ACCUMULATION	KNOWLEDGE ACQUISITION	KNOWLEDGE CODIFICATION
DIVERSITY		• common knowledge base • innovations and advancements	
INTERDEPENDENCY	• trust mechanisms • on-site training	• economies of repetition • collection of feedbacks • cross-fertilisation of competences	• systematisation of interfaces • improvement of standard procedures • organisational redesign

DYNAMICITY	• focused meetings • fluidity of informative process		• specific management tools • systematic reviews
UNCERTAINTY	• informal procedures • overcoming of "cultural gap" for knowledge sharing		

Focusing on the levels of single dimensions of project complexity, we can observe the prevalence of single processes of experience accumulation, knowledge acquisition and knowledge accumulation. For instance, a higher level of both interdependency and dynamicity results in a higher knowledge codification, to be promptly shared in the emergent knowledge communities. Beyond the experience of the project team members, dealing with several interfaces (e.g. customers, suppliers, subcontractors, other functional units) and pace of the projects (e.g. introduction of several changes during the implementation phases or strict regulations) allows for a better learning at organisational level to be translated in common knowledge repositories. A higher diversity mainly results in the need to acquire knowledge from the external sources, especially from the previous projects, the past experiences of the team members and also the competences of the main stakeholders, when properly shared. The dimension of dynamicity results in both knowledge acquisition and codification, mainly addressing issues that are specific of the ongoing project at the operational level. Finally, higher uncertainty requires relying on the ongoing experience-based learning.

Overall, the complexity of projects tends to bring to informal mechanisms of knowledge acquisition and codification, to be properly shared and transferred in the upcoming projects.

6. Conclusions

This study explores how organisations are dealing with the increasing complexity of their projects for developing new products from an organisational learning perspective. Focusing on the processes of experience accumulation, knowledge acquisition and knowledge accumulation, the resulting interpretative framework for complexity and organisational learning in project environments determines further insights on studying organisational learning as an emergent process. In general, complex projects show a considerable level of all the sub-processes of organisational learning, taking place in the project teams, with differences accordingly to the dimension of complexity.

This study contributes to the stream of literature on project complexity by enriching it with an organisational learning perspective. It can be situated at the interface between project

management and organisational studies, offering insights for a theory building aimed at studying organisational learning in project environments as an emergent process of complexity.

6.1 Theoretical and managerial contributions

This study represents, according to the knowledge of the researchers, among the first studies to link complexity dimensions and learning mechanisms in project environments. From a literature point of view, this paper contributes to the stream of literature on project complexity by enriching it with an organisational learning perspective. The study can be situated at the interface between project-oriented and organisational studies, offering insights for a theory building aimed at studying organisational learning in project environments as an emergent process for facing complexity. The findings are likely to advance knowledge on the issues of managing projects characterised by a level of complexity. Specifically, the study acknowledges the importance of considering the emerging and dynamic features of complexity from the point of view of the experience accumulation, knowledge acquisition and codification mechanisms of project management teams when facing complexity. Moreover, it aims to provide methodological contributions by employing an embedded case study design, including more sub-units (i.e. project teams) in the contextual setting of a single organisation (i.e. a project-based one).

Finally, the paper can provide some useful indications for the development of projects with reference to the definition, assessment and management of project complexity. The proposed dimensions may help project managers and other project stakeholders to better understand the complexity of the projects they are working on. This approach would support them in positioning their projects in terms of emerging patterns and their fit with the knowledge management strategies actually promoted within their organisations. A dedicated evaluation would provide them with a basis to eventually adjust their project management practices and/or organisational learning processes accordingly. In this sense, the results of the research can be of importance for practitioners as it suggests mechanisms and points of view to consider when dealing with the complexity of their projects, especially considering the perspective of the organisational process that takes place within projects in an organisation that generally develops more projects to realise its strategic objectives.

6.2 Limitations and suggestions for further research

The results of this study should be viewed in light of several limitations. Major limitations are linked to the choice of the research design, i.e. the single case study and the qualitative data

analyses performed, that limits generalisability. Despite this, this explorative study allowed to reveal possible patterns, and a statistical analysis on a wider sample would sustain a better formulation of the hypotheses and operationalisation of the variables. As regards the employed methods, the collection of data by informants may be difficult and in certain cases biased, but significant efforts were done by us to maximise the reliability, for example by using multiple data collection techniques and interviewing multiple informants.

Moreover, the selection of the case and the boundaries established in the design of the research limited the scope of the study. Therefore, a multiple case study, on a multi-sectoral basis, would allow to extend and refine the lessons learned here. Caution is required in extending findings to companies of different dimensions (e.g., small and medium enterprises), belonging to different industries (e.g., the manufacturing sector), and with different organisational settings (e.g. not pure project-based ones). A further interesting direction for future research concerns the selection of managerial and organisational practices to foster organisational learning with different levels of diversity, interdependency, dynamicity and uncertainty. Additional studies may be conducted to formalise and empirically test a model per each dimension of complexity and each learning process to be studied.

7. Bibliography

Baccarini, D. (1996). "The concept of project complexity – a review." *International Journal of Project Management*, Vol. 14, No. 4, pp. 201-204.

Bartsch, V., Ebers, M. and Maurer, I. (2013). "Learning in project-based organizations: The role of project teams' social capital for overcoming barriers to learning." *International Journal of Project Management*, Vol. 31, No. 2, pp. 239-251.

Blindenbach-Driessen, F. and van den Ende, J. (2010). "Innovation in project-based firms: The context dependency of success factors." *Journal of Product Innovation Management*, Vol. 27, No. 5, pp. 705-724.

Bresnen, M., Goussevskaia, A. and Swan, J. (2004). "Embedding New Management Knowledge in Project-Based Organizations." *Organization Studies*, Vol. 25, No. 9, pp. 1535-1555.

Cooke-Davies, T., Cicmil, S., Crawford, L. and Richardson, K. (2007). "We're Not in Kansas Anymore, Toto: Mapping the Strange Landscape of Complexity Theory, and Its Relationship to Project Management." *Project Management Journal*, Vol. 38, No. 2, pp. 50-56.

Davies, A. and Brady, T. (2000). “Organisational capabilities and learning in complex product systems: towards repeatable solutions.” *Research Policy*, Vol. 29, No. 7-8, pp. 931-953.

Eisenhardt, K.M. (1989). “Building Theories from Case Study Research.” *The Academy of Management Review*, Vol. 14, No. 4, pp. 532-550.

Maylor, H. and Turner, N. (2017). “Understand, reduce, respond: project complexity management theory and practice.” *International Journal of Operations & Production Management*, Vol. 37, No. 8, pp. 1076-1093.

Mitleton-Kelly, E. and Ramalingam, B. (2011). “Organizational learning and complexity science: exploring the joint potential.” In Allen, P., Maguire, S. and McKelvey, B. (Eds.), *The Sage Handbook of Complexity and Management*, Sage Publications, London, UK, pp. 349-365.

Prencipe, A. and Tell, F. (2001). “Inter-project learning: processes and outcomes of knowledge codification in project-based firms.” *Research Policy*, Vol. 30, No. 9, pp. 1373-1394.

Shenhar, A.J. (2001). “One size does not fit all projects: exploring classical contingency domains.” *Management Science*, Vol. 47, No. 3, pp. 394-414.

Shenhar, A.J. and Dvir, D. (1996). “Toward a typological theory of project management”. *Research Policy*, Vol. 25, No. 4, pp. 607-632.

Stjerne, I.S. and Svejenova, S. (2016). “Connecting Temporary and Permanent Organizing: Tensions and Boundary Work in Sequential Film Projects.” *Organization Studies*, Vol. 37, No. 12, pp. 1771-1792.

Vidal, L.-A., Marle, F. and Bocquet, J.-C. (2011). “Measuring project complexity using the Analytic Hierarchy Process.” *International Journal of Project Management*, Vol. 29, No. 6, pp. 718-727.

Yin, R.K. (2013). *Case Study Research: Design and Methods (Fifth Edition)*. SAGE Publications, Thousand Oaks, CA.