Proceedings of OLKC 2017 :11th Organizational Learning, Knowledge and Capabilities Conference, 26 - 28 April 2017, Valladolid, Spain
Available online http://www.olkc2017.com/event_detail/4239/sections/3417/program.html

The Role of Knowledge Resources in Managing Project Complexity

Juani Swart, *University of Bath*, J.A.Swart@bath.ac.uk
Neil Turner, *Cranfield University*, neil.turner@cranfield.ac.uk
Harvey Maylor, *Said Business School*, harvey.maylor@sbs.ox.ac.uk
Isabel Prieto Pastor, *University of Valladolid*, isabo@eco.uva.es
Natalia Martín Cruz, *University of Valladolid*, ambiela@eco.uva.es

Abstract

In this paper we consider the nature of project complexity and draw on current literature to make the argument that we do not yet understand fully which resources managers draw on and how they then respond to the range of complexities they face. We consider the role of knowledge resources underpinning complexity responses, and ask the research question "*What is the role of knowledge resources in managing project complexity?*" We then summarise the empirical work we have undertaken to date in investigating this. Looking at the aerospace industry, we find a range of responses to different forms of complexity, drawing on important human, social and organizational capital.

Introduction

Despite significant investment in management processes, systems and training, it is widely reported that the capability of organizations across the globe, in all sectors, still struggle to complete projects satisfactorily (Maylor, Turner and Murray-Webster, 2013). A reason for this is the complex nature of the work, and although a wealth of knowledge is available in professional bodies of knowledge (e.g. APM, 2012; PMI, 2013), this appears to be insufficient in improving project performance. Acknowledging this challenge, the nature of complexity in the context of projects has been a rich stream of research for a number of years. The aim of these researchers is not to give a 'simple' solution to the difficulties managers face – this is unrealistic – but to provide insightful analysis of the problems so that a more nuanced understanding may be obtained, thereby enabling more suitable responses to be crafted and to offer managers possible ways forward. In this work we build on existing literature to attempt to understand managerial judgement and practice better. We hence follow an approach of complexity *art* rather than complexity *science*. Accordingly, we begin our paper with a brief approach to literature on project complexity. Next, we show the initial stages of our research, undertaken in a Spanish aerospace company, and identify the significance of human, social and organizational capital in managing the complexities managers face.

Literature

We draw here on two bodies of literature. The first is that of project complexity, and we then show how this research can be furthered by investigating the nature of the knowledge resources used in determining complexity responses.

The nature of project complexity has been a challenge for both researchers and practitioners (e.g. Baccarini, 1996; Dvir and Shenhar, 1998; Jaafari, 2003; Maylor, Vidgen and Carver, 2008; Shenhar and Dvir, 1996; Tatikonda and Rosenthal, 2000; Williams, 1997, 1999; Xia and Lee, 2005). Although many organizations and consultancies have objective scoring mechanisms to give a numerical value of complexity when comparing one project against another, this is not necessarily as valuable as may be hoped for practicing managers, as the reality of dealing with the project will vary depending on an individual's experience. Williams (2005) calls for an understanding of what makes projects complex to manage, drawing on this 'lived experience' approach. Cicmil et al. (2009) differentiates between the complexity *in* projects and the complexity *of* projects. The former relies on a complexity science approach, the latter on individual subjectivity (i.e. the managers' perspective), and it is this complexity *of* projects view that we take in our work. We draw on Ackoff's (1979) view of managerial 'messes' which provides a clear and memorable view of the requirements of a manager:

> "Managers are not confronted with problems that are independent of each other, but with dynamic situations that consist of complex systems of changing problems that interact with each other. I call such situations messes… The behaviour of a mess depends more on how the solutions to its parts interact than on how they act independently of each other… Managers do not solve problems; they manage messes." (1979: 99-100)

The systematic literature review of Geraldi, Maylor and Williams (2011) identifies five distinct forms of complexity, namely structural, uncertainty, dynamic, pace, and socio-political. This was followed by Maylor et al. (2013) who merged some of these in creating the Complexity Assessment Tool (CAT) looking at three primary dimensions of complexity: *structural*, *socio-political* and *emergent*. Maylor and Turner (2017:6) define these as:

> *"Structural complexity*: increases with the number of people involved, financial scale, number of interdependencies within and without, variety of work being performed, pace, breadth of scope, number of specialist disciplines involved, number of locations and time-zones.
>
> *Socio-political complexity*: increases with the divergence of people involved, level of politics or power-play to which the project is subjected, lack of stakeholder / sponsor commitment, degree of resistance to work being undertaken, lack of shared understanding of the project goals, lack of fit with strategic goals, hidden agendas, conflicting priorities of stakeholders.
>
> *Emergent complexity*: increases with novelty of project, lack of technological and commercial maturity, lack of clarity of vision / goals, lack of clear success criteria / benefits, lack of previous experience, failure to disclose information, rising to prominence of previously unidentified stakeholders, any changes imposed on or by the project."

Although the CAT allows the identification of different forms of complexity (and hence a method of distinguishing different categories of 'complex project') an underlying theory of how to respond to these was still not available. Maylor and Turner (2017) subsequently proposed that structural complexities could be aided by a 'planning and control' response, socio-political via a focus on relationship-building, and emergent by enabling flexibility. Their workshop data, though, showed that management practices were in fact more nuanced than this and that these three approaches were not limited to their 'corresponding' complexity on the diagonal of the model. Examples are given in Table 1, showing that, for example, a relational approach to structural complexity would be to prioritise relationships with key stakeholders to keep them informed of progress, and in an uncertain environment a strong focus on effective risk management and change control can reduce the likelihood of unwanted 'surprises'. Practical responses, therefore, are not limited to the diagonal of the model.

	Structural	**Socio-political**	**Emergent**

Planning and control	Initiating, planning and monitoring.	Communications plan development. Implement project board of stakeholders.	Risk management. Change control.
Relationship development	Prioritise communications with stakeholders.	Teambuilding. Invest in social capital.	Socialise changes. Increase informal communications.
Flexibility	Change control. Anticipate change. Parallel development.	Manage expectations of change.	Agile project management. Entrepreneurial management approach.

Table 1: Relating complexities and responses (from Maylor and Turner, 2017).

Although Maylor and Turner (2017) showed that these forms of responses are used by managers, as yet we lack a comprehensive view both of the prevalence of such responses and, as it seems reasonable to posit that they may hinge on them, of the knowledge resources that are used to develop them.

In order to manage complexity, organizations need to rely on resources such as the knowledge and skills of their employees and relationships within the projects, the organization and also relationships external to the firm, such as suppliers and/or collaborators. We refer to these resources as forms of capital, i.e. a knowledge resource (Swart, 2006). That is to say, it is knowing how to draw on relationships and how to make use of skills and experience that enable the organization to manage complexity. In particular, we are interested in two broad categories of capital; i.e. human and social capital. Human Capital theory (Becker, 1964) uses economic logic to study individual decisions dealing with investments in productivity-enhancing skills and knowledge. Most definitions of HC state that it comprises knowledge, skills, intellect and talent of individuals (regardless of whether the context of the firm). Human capital theory further differentiates between the different branches of specialization that individuals may hold. For example, skills and experience can be tailored to fit the organization (firm-specific) or the client or market (industry-specific).

Social capital refers to the value that relationships hold in organizations. It is broadly categorized into cognitive, structural and relational (e.g., trust) aspects (Nahapiet and Ghosal, 1998). The previous research in the area of social capital broadly takes a network perspective, i.e. the network of relationships that an individual or an organization may have at any particular point in time. Hence there is frequent reference to the structural density of a particular network of relationships (Burt, 1992). In this paper we pay attention to how the social capital within and external to the firm is seen as a resource to manage complex contexts.

We do acknowledge that organizations do not inly rely on people and relationships but they also build organizational level responses to manage complexity. Hence, we need to pay attention to organizational capital, which we define as the processes, systems and technologies which are present in the organization and which individuals can draw upon when managing complexity.

The value of human capital is tied to social capital (Subramanian and Youndt, 2005) and although each may play a determinant role, they may act also in combination to develop responses to complexity. Our research question was therefore "*What is the role of knowledge resources in managing project complexity?*".

Method

To investigate further the nature of managerial responses to complexity we chose qualitative methods to allow us to gather rich data from respondents. The interview protocol developed looked firstly at the nature of complexities that the managers faced, both general and with respect to critical incidents in the life of the project. The particular responses were then investigated to understand what the managers did in relation to the identified complexity. The next stage was to probe the human capital and social capital aspects. The HC questioning looked at areas including the nature of managerial expertise, technical domain knowledge, knowledge of and in the client organization, and particular knowledge specificity. The social capital aspects included the social structure and stakeholders, relational aspect such as social norms and trust, knowledge sharing, client contact, and the nature of the social relationships and communications. In terms of organizational capital we asked about the processes and systems within the organization available to manage complexity. We thus sought to understand not only the nature of the complexities, but the responses and the knowledge resources utilized in their development.

The empirical data is in the process of being collected and analysed. We have chosen a range of public- and private-sector organizations deemed likely to have complex projects. At the time of writing we have interviewed eight managers within a Spanish aerospace company. This company specializes in design, manufacturing and assembly of high technology aerostructures and engine components for major clients. It was founded in the 1970s and has over 1000 staff, working within manufacturing plants in Spain and Portugal. Its work includes engineering, manufacturing, integration, customer support, innovation and quality management. The clients mostly belong to the aeronautical industry. As a first level supplier (Tier 1), the firm's value chain encompasses all activities related to the design, development, manufacture and integration of structural assemblies for the aerospace industry. The Company has a Centre of Excellence in the integration of aerostructures, located in Spain, and specific areas and specialized equipment on assembly lines at each of the firm's facilities. It thus maintains a strong commitment to the encouragement and the development of new technology and promotes continual research and development. The company has participated, since 2002, in a number of European R&D projects. Currently the main research activity focuses on composite materials. The innovation of the team has led to the search for the application of their skills and knowledge to new projects outside the aeronautical sector, which in a number of cases has resulted in the award of new patents. They have also received several awards for efficiency that recognize the quality and performance of the company.

We conducted in-depth interviews with a representative sample of managers and staff belonging to two main ongoing aerospace projects within the company. We sought to understand the main complexities facing each project and to identify the suitable human and social capital resources that are central to each piece of work. We first interviewed the Projects General Manager of the firm to get a general overview of the main challenges for the firm and the two projects we investigated. For each, we interviewed the project manager, an engineering manager responsible, and an operations manager. Second, we interviewed the quality manager responsible for the quality requirements involved in both pieces of work. The interviewees were prompted to refer to the main problems and conflicts emerging during the project, and to comment on the importance of his/her human capital, as well as that of other participants, and social capital to accomplish the work.

	Project 1	Project 2	Total
Projects General Manager	-	-	1
Project Manager	1	1	2
Manufacturing Engineer	1	1	2
Quality Manager (works on both projects)	1	1	1
Operations Manager	1	1	2

Table 2: Data collection from Aerospace company.

Results

All the interviews were fully transcribed and analysed in NVivo. Our first task was to ascertain the nature of the complexities they faced. From the coding data, we noted that 70% of the complexities were structural, 19% were socio-political and 11% were emergent. This may not be surprising given the technical, engineering-based, nature of the work. Examples are given in Table 3.

Complexity	Examples from the data
Structural	"So, now it's time to deliver and he has no time and the delivery date is not moving to the right. So, instead of having the three months he requested, he only has three days." "A lot of parts in that aircraft don't even change but one of the things that changes is the flap. The flap is new because it has to support bigger loads. We have to face a decrease in the weight of the part itself so it's a big challenge engineering-wise, design-wise, manufacturing-wise. It is a big, big, challenge and that is what we are struggling with right now. It's one of the most complicated parts we've had to manufacture ever."
Socio-political	"I understand the client has to control you. I can understand it but they take a lot of time to talk to them, to explain things, and from my point of view, sometimes it is a waste of time. I spend lots and lots of hours trying to explain things just because we have here every week two people coming from [Client]. You have to talk to them, to explain what you are doing, why you are doing this and not the other thing. I don't really think that that's helping us because they do not give you some new ideas or some way of think of something. It's just to inform people what you are doing and why you are doing this. " "Well, it's always a problem because at the end you have your engineering teams that have to work together with (the others) foreign teams. Each one, each side

	has its own interests always. But yes, it's a challenge, it's again interesting, it's new for us so that's the way this program works."
Emergent	"It's actually new [technology] for the industry in general. Of course for this company, but also for the industry. So, if we succeed it will be very very good for us and for this company but it is very challenging. So, we're facing a lot of trouble. We are now facing a lot of pressure as well because we've already delivered some articles for flight test aircraft. But now, we have to deliver our first aircraft for a real customer." "I try to spend a lot of hours each day with them, participating in their meetings or in their manufacturing itself because I think it's really important for me to have the feeling of what's going on by myself. So, when it comes to making decisions with the client, I can bring this information over with me. When the client says "I want you to do five tests next week" I have the information to say "No, I can only do three because this and this has to happen" "Usually, it is a different part and if we don't produce something similar, we have to start from zero. If we don't have previous experience it's complicated to start to define because there's no way to know how to do it."

Table 3: Examples of complexities.

Interestingly, with such a high percentage of structural complexities, we might have imagined that there would be similar amount of 'planning and control' responses along the diagonal of Table 1 (Maylor and Turner, 2017). However, the analysis in fact showed that planning and control accounted for only 47% of the coding, with 'relational' accounting for 39% and 'flexibility' for the remaining 14%. 'Social' responses thus account for a seemingly disproportionate amount of the data. Examples of the responses are given in Table 4.

Response	**Examples from the data**
Planning and Control	"In this case, production guarantees that you have the means, resources and that it is manufactured according to what they define. Production cannot intervene in changing any work sequence or any of the operations. It all has to be supervised by engineering." "If it is a problem that we have with a machine that doesn't have the capacity to meet demand, we then get sub-contracting involved to look for a supplier that can find us another machine where we can sub-contract."
Relationship	Basically, what we did is to create a very collaborative activity from our engineering, design and stress engineering activities to manufacturing engineering activities. So my role, which was a project manager, created an atmosphere, tried to create an atmosphere with the team, not only the design engineering team, stress engineering but manufacturing engineering in all of the different technologies. So we had a common and unique target so we were all working towards achieving that target." "[A]ny time something happens you have to transmit through internally, externally to everybody and to be aware of what happened, and being transparent, not trying to hide anything."

	"We have a lot of meetings for brainstormings, a lot of testing, a lot of meetings to evaluate results, put results on the screen, and let everybody share their points of view, and it's been really really useful. But, I think this is challenging for everyone, not only for us. There's people with a lot of experience that are struggling to be able to help us as well. But, we will get there."
Flexibility	"Any deviation in production, in quality, we start what we call here "an improvement event", where different solutions are put forward. We look for the root cause of the problem and try to solve it." "So, we start thinking in the tool and then we define like a set of tests, like a test campaign to verify that we can do that that way. We start. Maybe, first attempt we fail. Then we have to re-think and we have to start again from the beginning to discard one concept."

Table 4: Examples of complexities.

Responding to complexities thus not only required specific human capital (e.g. the requisite technical knowledge) but also significant interpersonal skills and social capital in order to implement solutions. These included being able to work with a range of internal and external stakeholders, and we discuss this further in the next section.

Overall, when analysing the complexities mentioned and the responses enacted, we identified that all nine of the elements within Table 1 could in fact be populated. The systematic coding is a detailed and traceable method that enables us to understand both the nature of the complexity and the type of response. Examples of the findings are given in Table 5.

	Structural	Socio-political	Emergent
Planning and control	Systems and controls to deal with the design and manufacturing processes. Planning to converge to client requirements	Client requests changes based on a strong relationship but these need to go through engineering for technical evaluation before agreeing.	Unexpected production problem can require meetings to be held and a specific action plan generated.
Relationship development	Working with customer to devise a solution to design issues. Very collaborative activity in all stages (from design to manufacturing).	Need to ensure a good relationship with the client when unexpected problems occur. Need to get confident on people.	When one of their major customers' needs a part urgently then they will supply because they have a good relationship with the buyer.

Flexibility	Working to solving initial design problems by using novel solutions.	Accommodating redesigns at short notice to keep the client happy and support the relationship.	"Any deviation in production, in quality, we start what we call here "an improvement event", where different solutions are put forward. We look for the root cause of the problem and try to solve it."

Table 5: Examples: Complexities and management responses.

Resource Utilisation

The coding used in the analysis looked at human capital (focusing on client-, firm-, industry- and role-specific knowledge) and social capital (both collaborative and opportunistic in terms of activities, as well as its effect on flexibility, knowledge-sharing, shared norms and trust).

In terms of human capital, knowledge specificity was identified as important, but this was often not as clear-cut as may be expected. There was a clear indication that industry and role specific knowledge was important. Our respondents often referred to the importance of engineering specific skills and experience and explained that this was deeply ingrained in their practices. Client knowledge was valuable, as different clients have distinct ways of working, but transferring into the industry from elsewhere was relatively common and seemingly relatively straightforward.

> "Moving after 10 years was hard. But I probably felt comfortable here after working six months."

Specialist knowledge embedded with and in subcontractors was challenging, though, and transferring between subcontractors could be difficult, for example when much of the technology was specific and needed a deep understanding of the particular context. Interestingly, client-, firm-, industry- specific knowledge had a broadly equal number of coding instances, but role-specific knowledge had significantly less. It should be noted, however, that a firm delineation between the aspects was sometimes hard to ascertain, they overlapped in terms of the interview and it was difficult to identify them as stand-alone constructs.

In terms of the collaborative or shared work issues, shared targets were the most highly coded, covering not only co-development with their major clients, but also intra-company collaboration to ensure consistency. Opportunistic social capital had less than half the number of coding instances, but the major issue appeared to be that the client could situate an individual or team directly within their supplier. This was intended to ensure greater transparency and smoother operations (i.e. the intention was positive) but in reality could lead to frustrations and time spent reporting rather than problem-solving. This subtle issue had a direct impact upon the ability to manage complexity. For example, when a client engaged in an opportunistic manner by placing staff with the organisation and controlling targets and quality directly, it became all the more important to draw on social capital to move the project along in order to secure innovate outputs.

Other issues that were coded highly were the frequency of communications (both inter- and intra-company) and the importance of knowledge sharing across and between projects. This is perhaps to be expected as these are significant factors that would be expected. However, the coding instances for 'trust' and 'shared norms' were less than half these amounts. These factors would also be expected to be important, and it is not clear whether this relationship reflects relative importance or whether it is a function of the limited date collected so far in the investigation.

Conclusions

The detailed initial data analysis has shown a range of responses to the complexities identified within this aerospace organization. More data will be collected in different organizations and this may also provide further insight. These findings illustrate that the specific aerospace organisation is faced with a myriad of complexities. One may initially assume that this will be related to structural complexity given the technical nature of the projects. What we find, however, is that there is intense socio-political complexity, which is linked to the cross-national and inter-disciplinary nature of the innovations. There were several examples where the contracting organization had very specific technical requirements that were used to control the project processes and outcomes. Balancing differences in viewpoints in these situations is critical. So, itt was particularly in these situations where relational knowledge was drawn upon to resolve tensions and to move the project along.

The framework of Table 1 allows us to understand the nature of each complexity and the nature of the response (i.e. also indicating the relative prevalence of each), and the particular knowledge that is being utilised for that response. It is important to note that organisational capital does remain critical in resolving complex issues. This can clearly be seen in situations that draw on technical specifications and mutually agreed project plans. In many ways the organisational capital created a framework within which the fluidity of social capital enabled suitable complexity reponses.

The analysis has shown that human capital (specifically expertise, judgement and contextual knowledge) is vital for managers to reach initial conclusions regarding decisions that need to be made about the complexities they face. In so doing, firm-specific knowledge does not seem to be as important as client or industry-specific knowledge. However, facing work and its complexities require getting confident on people, knowing how they are, listening them, but always defending client requests. Networking is really important, both with and outside the company. This is situated within the social setting of the project and social capital is essential in (1) understanding 'who knows what' and therefore accessing the knowledge of others, (2) integrating complex knowledge among the project participants, and (3) understanding and building relationships such that responses can be carried out effectively in the team and wider stakeholder context.

There are clear limitations to our study. Firstly, we have one case study organisation with multiple projects. It would be ideal to study several organisations in order to develop a typology of complexity responses. Secondly, we adopted a qualitative methodology which does provide a rich source of data but is less generalizable. This research could therefore be complemented by further quantitative methods. Thirdly, we focused on a single industry sector in order to control for the various complexities that may occur. Future work could benefit from a cross-industry analysis to compare complexity responses.

References

Ackoff R. (1979) “The Future of Operational Research is Past” Journal of the Operational Research Society, 30 (2) 93-104.

APM, 2012. Body of Knowledge, Sixth ed. *Association for Project Management*, High Wycombe, UK.

Baccarini, D., 1996. The concept of project complexity - a review. *International Journal of Project Management*. 14 (4), 201-204.

Becker, G. (1964) *Human Capital*. New York: Columbia University Press.

Burt, G. (1992) Structural holes, Cambridge: Harvard University Press

Cicmil, S., Cooke-Davies, T., Crawford, L., Richardson, K., 2009. Exploring the complexity of projects: Implications of complexity theory for project management practice. Newtown Square, PA: PMI.

Dvir, D., & Shenhar, A., 1998. In search of project classification: a non-universal approach to project success factors. *Research Policy*. 27 (9), 915-935.

Geraldi, J.G., Maylor, H., Williams, T. 2011. Now, let’s make it really complex (complicated): A systematic review of the complexities of projects’, *International Journal of Operations & Production Management*, 31(9), pp. 966–990.

Jaafari, A., 2003. Project management in the age of complexity and change. *Project Management Journal*. 34 (4), 47-57.

Maylor, H., Turner, N., Murray-Webster, R., 2013. How hard can it be? Actively managing complexity in technology projects. *Research Technology Management*. 56 (4), 45–51.

Maylor H. and Turner N. 2017. Understand, Reduce, Respond. Project Complexity Management Theory And Practice*. International Journal of Operations and Production Management* (forthcoming).

Maylor, H., Vidgen, R., Carver, S. 2008. Managerial complexity in project-based operations: A grounded model and its implications for practice. *Project Management Journal*. 39 (S1), 15-26.

Nahapiet, J., & Ghoshal, S. (1998) Social capital, intellectual capital and the organization advantage. *Academy of management review*, 23(2), 242-266

PMI, 2013. A guide to the project management body of knowledge PMBOK, fifth ed. *Project Management Institute*, Pennsylvania, USA.

Shenhar, A. J., Dvir, D. 1996. Toward a typological theory of project management. *Research Policy*. 25 (3), 607-632.

Subramaniam, M. and Youndt, M.A. (2005) The Influence of Intellectual Capital on the Types of Innovative Capabilities. *Academy of Management Journal*, 48 (3), 450–463.

Swart, J.(2006) Intellectual capital: disentangling an enigmatic concept, *Journal of Intellectual Capital*, 7(2), pp. 136-159

Takeuchi, R., Lepak, D., and Swart, J. (2011) How organizations evaluate and maintain fit of human capital with their needs. In A. Burton-Jones and J-C Spender (eds): Oxford Handbook of Human Capital: UOP. Pages 333

Tatikonda, M. V., Rosenthal, S. R., 2000. Technology novelty, project complexity, and product development project execution success: A deeper look at task uncertainty in product innovation. *IEEE Transactions on Engineering Management*. 47 (1), 74-87.

Williams, T., 1997. Managing and Modelling Complex Projects: Kluwer Academic Pub.

Williams, T., 1999. The need for new paradigms for complex projects. *International Journal of Project Management*. 17 (5), 269-273.

Williams, T., 2005. Assessing and moving from the dominant project management discourse in the light of project overruns. *IEEE Transactions on Engineering Management*. 52 (4), 497-508.

Xia, W., Lee, G., 2005. Complexity of information systems development projects: Conceptualization and measurement development. *Journal of Management Information Systems*. 22 (1), 45-83.