Requirements for Firms Designing Megaprojects

Christian Brockmann[1]

Abstract

Megaprojects are interesting objects of study for two reasons. On the one hand, they are the most complex undertakings in construction. They extend the boundaries of our knowledge. On the other hand they work like magnifying glasses; they unveil problems that might remain unnoticed on smaller projects. As such, they help us to better understand the mechanics of all types of construction projects.

The design of megaprojects is based on the conceptualisation of the owner and it poses different problems than execution of works. Understanding the requirements imposed by the design task of megaprojects helps both the owner and the design firm. The owner will be able to make a better choice when awarding the design contract and the design firm can better evaluate whether it possesses the know-how and resources demanded. The framework for such an evaluation is provided by the concept of complexity, which in turn is founded in Luhmannian system theory.

The research methodology takes a qualitative approach by using grounded theory and expert peer interviews. Such interviews are not often discussed in construction research. Eighteen interviews were conducted with a total of 98 interviewees. The groups of interviewees ranged from three to eleven in size and all members were design professionals. The group of the interviewers comprised five members; they were both, academics and professionals.

Two aspects emerged as most important: Megaprojects demand experience and integration is the most challenging task. The required experience comes from a number of sources: megaproject experience, international experience, local experience, management experience, system experience, and specific design experience. All these different experiences are necessary for the integration through technical interfacing, cooperation, coordination, and communication. In sum, the lessons learned are: It’s the experience, stupid!

Keywords: Complexity, design, experience, expert peer interviews, megaproject

[1] Professor; Civil Engineering; University of Applied Sciences Bremen; Neustadtswall 30, 28199 Bremen, Germany; christian.brockmann@hs-bremen.de

1. Introduction

Megaprojects are invariably described by using superlatives (the prefix “mega” is already one of them). They are called the “giants” among projects (Grün, 2004) or the “new animal” (Flyvbjerg et al., 2003). While such projects are large, they are not unparalleled in history. Examples of megaprojects are the pyramids of Giza or the Suez Canal.

Not all authors use the label “megaproject”. Some refer to them as large-scale engineering projects (LSE-Projects, Hassan et al., 1999) and describe them by five attributes: (1) “high” capital cost, (2) “long” duration but program urgency, (3) technologically and logistically demanding, (4) requiring multidisciplinary inputs from many organizations, and (5) leading to a “virtual enterprise” for the execution of the project. Grün (2004) puts the emphasis on the aspect of multi-organisational enterprises and characterizes these by (1) singularity, (2) complexity, (3) goal-orientation (technical, financial, time) and (4) the nature and number of project owners.

When considering these attributes together, then megaprojects are indeed daunting tasks. This is only the more true since cost and time overruns are typical. The list of projects with cost overruns reads like a “who is who” in megaprojects (Flyvbjerg et al., 2003); among these are the Suez Canal (1,900%), the Sydney Opera House (1,600%) or more recently the Boston Artery Tunnel (196%), the Great Belt Rail Tunnel (110 %) and the Channel Tunnel (80%). Reasons given are planning optimism, mistakes, and political lies.

Considering the design of megaprojects, important attributes are based on Hassan et al. and Grün:

- High capital cost and long duration with program urgency leading to a high density of design tasks over a longer period
- Technologically demanding design due to singularity and complexity of the projects
- Multidisciplinary input also for the design
- Virtual enterprise including project owners

2. Complexity

2.1 Definition

Sargut and McGrath (2011) define a simple system by a low degree of interaction and dependable predictability; complicated systems comprise many elements and many interactions functioning according to clear patterns, they are also predictable; complex systems are identified by the terms of multiplicity, interdependence and diversity, their outcomes are difficult to foresee. The same system configuration at the start allows for different results. Gidado (1996) is taking a different approach by concentrating on components (inherent complexity, uncertainty factors, number of technologies, rigidity of sequence, overlap of stages) and interactions between these. For him, complexity purely has a technical character. These positions represent two ends of a continuum for the definition of complexity: the first one is highly abstract and flexible, the latter one specific and more rigid. Seeing complexity not only from a technical perspective is a fairly new topic (Antoniadis et al. 2012). An abstract definition allows incorporating nontechnical perspectives and for this reason we will approach the definition of complexity from this end of the continuum.

It seems that the efforts of finding a definition converge on three characteristics with two of them (elements and interactions) being fixed and the third one under scrutiny. For this text, we propose the following definition of the term:

> Complexity = (def.) the number of elements, their interactions and the strength of impacts in a defined system with regard to decision making

It should be noted that this definition is a general one referring to any type of system. For a construct of construction project complexity we will need to find further dimensions. Complexity does not remain constant over the life span of the project. In the end, the aim is to reduce it by decision-making. Therefore, we are faced with different configurations of complexity at different times. Construction project complexity is subjected to dynamic change (Girmscheid and Brockmann 2008).

2.2 Dimensions of complexity

The discussion on complexity has progressed from just considering technical complexity to include other categories. Baccarini (1996) for example distinguishes between organizational and technological complexity. Girmscheid and Brockmann (2008) introduced task, social and cultural complexity based on Wilke (2000). Task complexity combines technological and parts of organizational complexity, especially planning and organizing. It excludes leadership, which is part of the social complexity. There can be little discussion that the number and diversity of stakeholders in a project along with the strength of their impact (interest and power – Chinyio and Olomolaiye 2010) increases its complexity; this we term "social complexity". The same holds true for the influence of culture on construction projects (Tijhuis and Fellows 2012, Kähkönen 2008). In all cultural studies the point is to show how much the stakeholders' cultural diversity influences project outcomes. The more cultures meet in a project, the more complex it becomes since it requires coordination of an increasing number of different cognitive maps (Brockmann 2009); this we term "cultural complexity".

Two additional forms of complexity can capture dynamics: cognitive and operative complexity. They both develop over time. Cognitive complexity mirrors how differentiated we think about a construction project; this increases with time as we understand a project better. Operative complexity is the degree of freedom for members of a project with regard to its operations and the project sponsors. Are most operations determined by the sponsors or does the project develop its own more specific operational approaches and thus become more complex? Both, cognitive and operative complexity mirror how much new we learn in a project.

A confined space influences task and social complexity. Restricted space for the tasks (i.e. a limited construction site) and social interactions (i.e. limited office space) increase these two types of complexity. All five types are becoming more complex as less time is available. This is a result of the decision-making perspective. The discussion can be summarized in a graph (fig. 1).

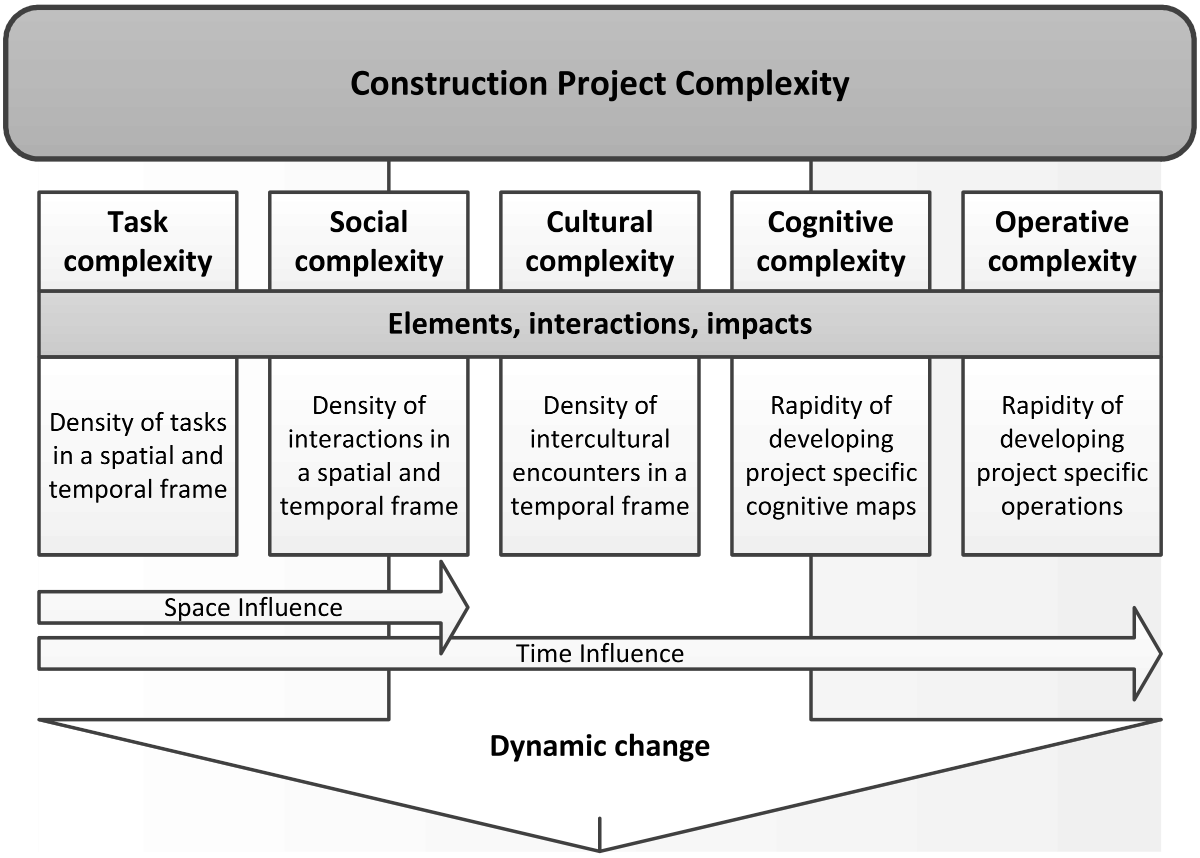

Figure 1: Dimensions of construction project complexity

3. Research Methodology

The research question is: What are important requirements for design firms with regard to megaprojects? In general, we are looking for a set of criteria belonging to the social world. A set of criteria in the social world can only be established through qualitative research. Grounded theory offers a possibility to establish such criteria (Glaser / Strauss 1967). A literature review on prequalification for design firms provided criteria which consequently were discussed by industry professionals and a set was chosen for the interviews. This is not a pure approach within grounded theory as the criteria were derived from the academic world and not grounded in the subject matter. However, the discussion and decision by industry experts remedied the deviation at least partially.

Two principles were applied which are commonly used in economics: (1) principle of individuality, i.e. all data are collected from individuals or actors; (2) principle of a non-individualistic view, i.e. description of a group behaviour or a firm. Propositions are derived from principle 2 through aggregation of data based on principle 1.

3.1 Interviews

Problem-centred expert peer interviews were chosen to collect data. This type of interview is not often discussed in research but it offers new possibilities in case that both, interviewer and interviewee have a similar background. This is true for all researchers in construction engineering management with a strong professional background.

The opposite form of interview is an ethnographic interview (Spradley, 1979). The basic assumption of ethnographic interviews is that the interviewee and the interviewer have different professional backgrounds and therefore use different professional languages with corresponding concepts and meanings. Accordingly, the interviewer must learn the language of the interviewee.

Expert interviews suffer from the same predicament since researchers such as social scientists interview subject matter experts. Design managers in civil engineering learn both during their education and in their business lives to speak in a professional language. They form a speech community. The professional language of a speech community is sharper and better defined than everyday language because of the higher degree of institutionalisation. Part of the university training that is indispensable for civil engineers is to define terms and thus it welds words and abstract patterns. A non-expert researcher will not easily distort the usage of the professional language by experts but misunderstandings are possible: The interviewer must still learn the language of the subject matter experts.

Meuser and Nagel name the following problems with expert interviews (2002): (1) The expert is not a real expert; (2) the expert talks more about internal matters and intrigues than about the interview subject; (3) he assumes alternatively the roles of an expert and a private person and (4) the expert gives a lecture and not an interview. All these concerns can be addressed by interviewing a group of experts and not individual experts and by using a problem-centred interview strategy. Witzel and Reiter (2012) describe such a strategy by its orientation towards a problem (such as requirements for design firms), by developing methods with regard to an object (e.g. megaprojects) and by process-orientation. The latter point is observed by using conversational entry, general and specific prompting and ad hoc questions. In a group of experts, chances of not interviewing subject matter experts decrease as objectivity in the form of intersubjectivity increases. General and specific prompting allows guiding the interview back to the problem.

The language problem can be solved by an interview design where experts interview experts; these are called expert peer interviews. They more or less take the form of a dialog between equal partners (Porter et al. 2009). The only exception is the problem-orientation and the right of the interviewer to guide the dialog back to the problem. Peer interviews allow solving the language predicament and they put both sides on an equal footing. The requirements for the interviewers are the only problem with peer interviews: they must be professionals in the field of research and scholars at the same time.

The most important advantage of expert peer interviews is their quality. Since there is no need to learn a different language, they can start at a very different point on the hermeneutical spiral and then lead to a deeper understanding.

Eighteen interviews were conducted by a group of five interviewers. In total, 98 subject matter experts were interviewed. The experts were representatives from eighteen international design firms. They were interviewed in groups where the smallest group of interviewees had three and the largest eleven members. They were asked about their previous experiences with megaprojects, i.e. a large aggregate of lessons learned.

3.2 Data recording and evaluation

During the interviews, the expert interviewees took notes. These notes do not have the character of paraphrasing. Instead, already during the interview the interviewees performed the process of open coding (Strauss / Corbin 1998). Open coding allows identifying and noting concepts in interviews. Open coding was completed during data evaluation. The final step was axial coding which helps to establish relations between categories and subcategories. The concepts derived from open coding are shown in the following figures (figure 2 to 5) in boxes and axial coding allows us to draw the connections between the boxes.

4. Data collection

Complexity is used as a conceptualisation of the term “megaproject” with its dimensions of task, social, cultural, cognitive and operative complexity. This is helpful for an academic approach; it is not clear enough for expert peer interviews. Therefore, we chose a 40 billion US dollar rail infrastructure project in the Middle East as an example. Rail infrastructure has the advantage of added complexity by the system it presents: Civil infrastructure, electronic signalling and communication, mechanical trains, operation and maintenance as well as financing are the larger subsystems.

It should be noted that all 98 interviewees are design engineers or design managers. They present a certain perspective of the problem “megaproject”. This shows for example in the following data, when reasons for cost increases and claims are attributed solely to owners and contractors but not to designers. Very basic common sense tells us that designer also make mistakes. To repeat, completeness was not an aim of this research only understanding the perspective of design firms. A broader picture of the risk of megaprojects was developed by Flyvbjerg et al. (2003).

4.1 Emerging criteria

Four criteria emerged during the interviews as salient for establishing requirements for design firms with regard to megaprojects. These criteria are:

- Strategic approach to designing megaprojects
- Success factors for the design of megaprojects
- Reasons for cost increases and claims in megaprojects

- Required qualifications of design managers and engineers for megaprojects

The criteria are not independent. Success factors will be part of the strategic approach and qualifications can be part of the success factors and the strategic approach. Mutually exclusive are success factors as they tell us what to do and reasons for cost increases and claims as they tell us what to avoid.

4.1.1 Strategic approach

Very clearly, integration is the most important concept used as strategic approach. Given the very demanding technical task one could expect that specialised knowledge would be named. However, it was not mentioned even once. Specific knowledge seems to be available so that the paramount task is integration of design. Open and axial coding yields the information contained in figure 2.

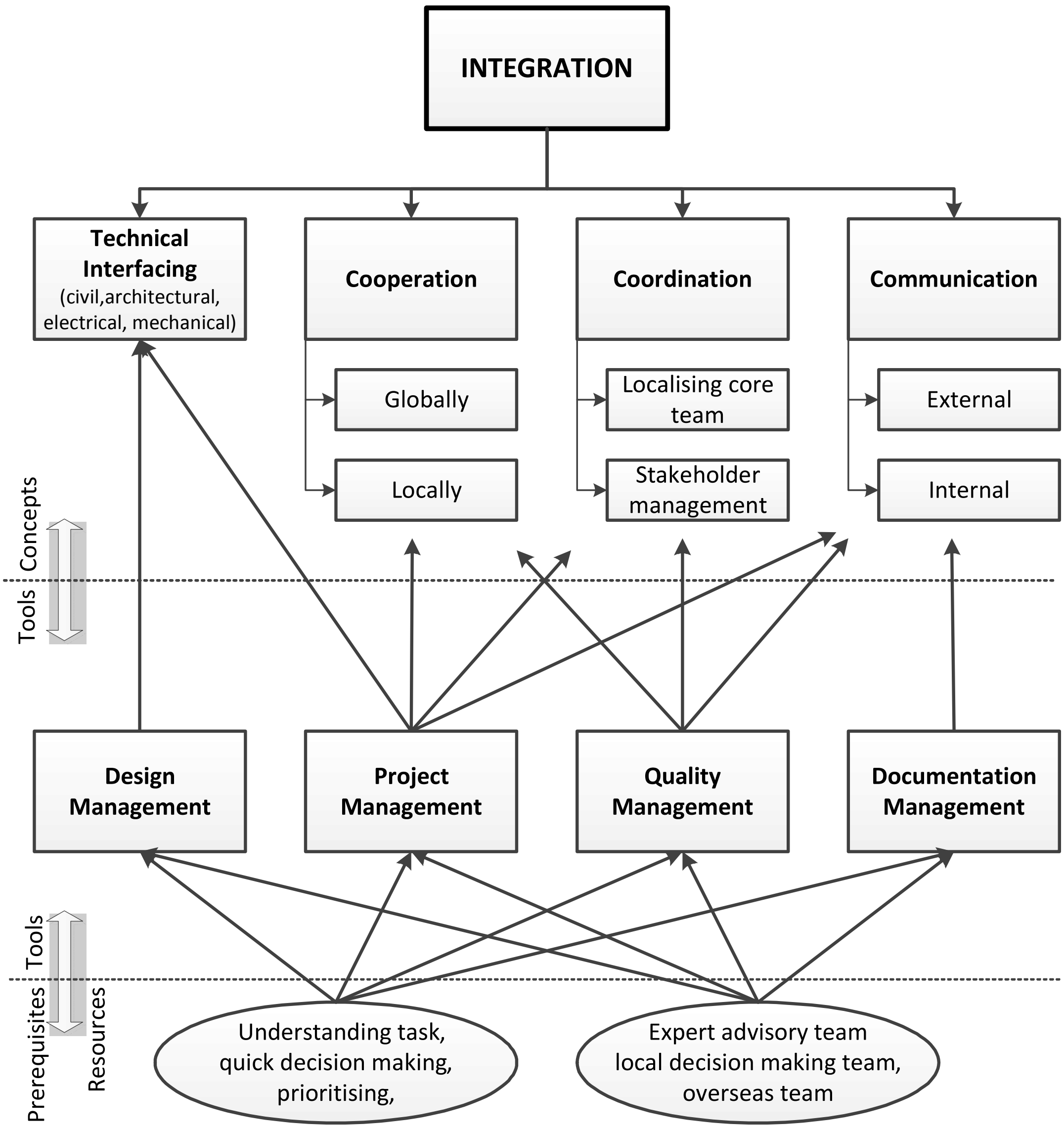

Figure 2: Strategic approach to megaprojects by integration

4.1.2 Success factors

A word of caution needs to be expressed in the beginning: Success factors should not be interpreted as unfailing mechanisms. Rather, they are shared cognitive maps of subject matter experts (Brockmann 2009). As maps they undergo constant updating and thus change. They are developed in a sense-making process that is coupled to the real world of construction. As such they are neither chimaeras nor natural laws.

We can expect a certain overlap between strategic approach and success factors. Nobody would choose a strategy that does not build on success factors. Success factors are seen more on an operative than on a strategic level. They can be divided into three categories: people, methods, and organisation. People and organisation were mentioned as part of the strategic approach. The methods are a repetition of those regarded as important for the strategic approach with a little more detail (figure 3).

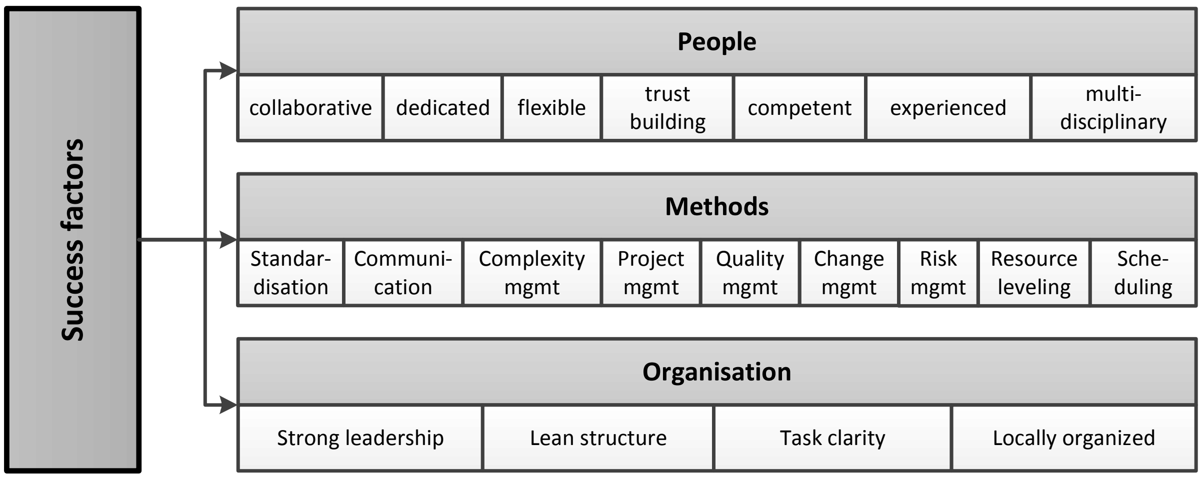

Figure 3: Success factors for the design of megaprojects

The required characteristics of the people working on megaprojects are no surprises. Important are the ability to work in a team (collaborative), to be flexible, and to be multidisciplinary. There is no mention of a need for specialised people. This supports the findings that integration is more important than specialist knowledge.

For the category of organisation the idea of a lean structure with strong leadership for integration is important. Too large an organisation makes solving the design task more difficult. In a lean structure multidisciplinary people are the key to success.

4.1.3 Cost increases and claims

Reasons for cost increases are attributed to the owner or external factors (figure 4). It was already stated that this is a one-sided view, excluding reasons for which designers are responsible. Slow decision-making and scope changes are most often mentioned. When there are scope changes and no functioning change management procedures coupled with slow decision-making, the situation becomes worse.

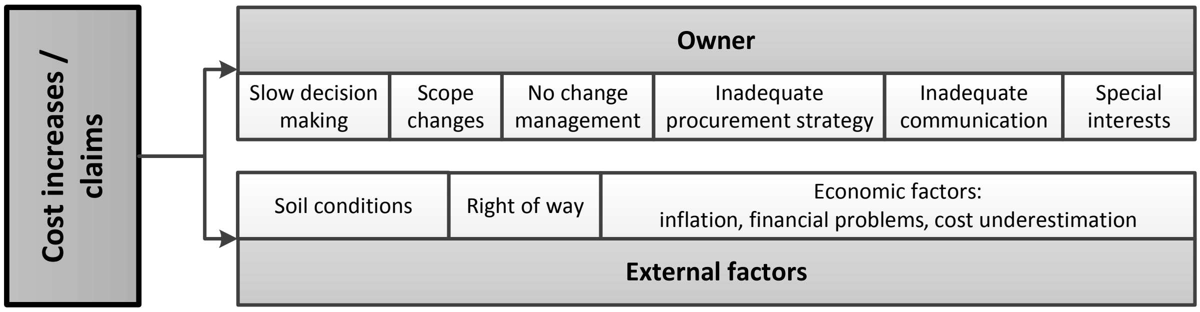

Figure 4: Reasons for cost increases in megaprojects due to design

An inadequate procurement strategy results in joining with the wrong contractors. Their lack of qualification and the choice of wrong contractual mechanisms lead to further cost increases. Additionally, claims are due to inadequate communication between owner, designers, and contractors. Sometimes the owner has other competing goals and he might put more emphasis on these than on the project success.

External factors for cost increases are soil conditions that differ from those given in the contract or a belated handover of the right of way. The owner is responsible for both in most cases, but sometimes he has no influence over them. Cost underestimates might be due to planning optimism or to political pressure. Clearly, the owner has no control over the inflation or financial markets.

4.1.4 Qualifications of key personnel

Reviewing the previous results, it becomes obvious that people are the drivers of the strategic approach, at the core of the success factors and a guarantee against cost increases. They must have the right experiences (fig. 5). The list of experiences is daunting; it seems almost impossible to find a project manager who fits into the picture. Therefore, we need to prioritise the experiences. Indispensable is megaproject experience or in more academic terms the ability to deal with the overwhelming complexity of megaprojects in all its facets (task, social, cultural, cognitive, operative). Managers who do not have command of the corresponding skills will make the wrong choices and the learning process takes time.

In second place come the international experience. International projects might not always be megaprojects but all international projects are large or special. Cultural competence is key to be successful in an international environment. Local experience can be provided by advisors in the beginning, but the key personnel must be able to build up local relationships quickly based on their cultural competence.

Management experience comprises project management, design management, and quality management. A special type of experience is system experience for the chosen example of railway infrastructure. This can be learned on the job as specialists will have the required interfacing knowledge. Specific design experience is then the knowledge base for specialists.

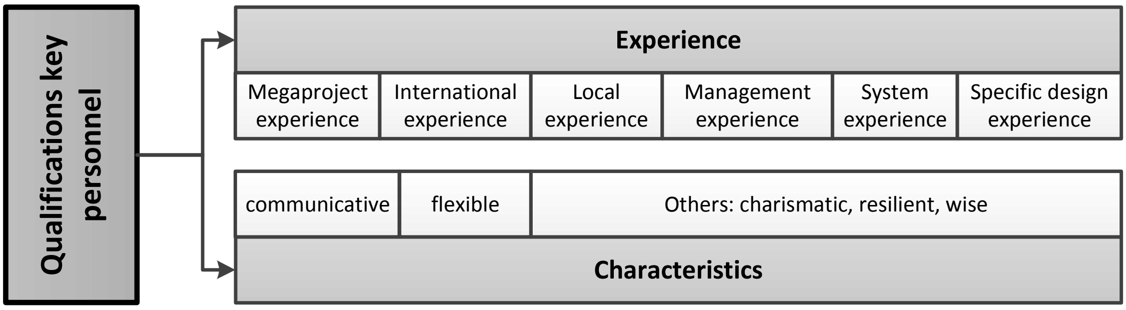

Figure 5 : Qualifications for key personnel

In sum, the project management team must first of all have megaproject, international and management experience. Local and system experience are secondary as they can be learned on the job. Specific design experience is the domain of highly specialised engineers.

5. Conclusion

Experienced people are the key to megaprojects. A balance is required between generalist and specialist experience. The specialists must provide in depth knowledge in their areas as the design of a megaproject often works on the cutting edge of our knowledge. However, the specialists are not the bottleneck to megaproject design success.

The management team which integrates all the different aspects of a megaproject, which breaks down task, social, cultural complexity and which expands the cognitive and operative complexity must be based on a wide range of experiences. It is almost impossible to find managers who possess all the required experiences. So, they must couple their available experiences with the ability to learn. The need to learn is not obvious for all experienced managers but megaprojects demand a respectful approach. Prioritizing the required experiences for the project management team provides the following list:

1. Megaproject experience (condition sine qua non)
2. International experience (condition sine qua non)
3. Management experience (condition sine qua non)
4. Local experience (can be learned)
5. System experience (can be learned)
6. Specific design experience (not required)

The overall conclusion is: It's the right experience, stupid! This seems simple but why do we so often get it wrong? Maybe because we do not heed the lessons learned as described above or maybe because we are not humble enough when taking on the task to manage a megaproject?

The consequences for design firms are clear: They must build up actors with as much required experience as possible. There must be a balance in the project team to cover all areas of experience. The project manager must understand that he alone is most likely not qualified enough for the task and needs the support of the team. The whole team must strongly seek more experience as the project advances and adapt previous lessons learned to the unique circumstances of the focal project. Integration of knowledge is more important than a hierarchical structure.

Companies should also ask themselves carefully whether they have a command of the required experiences. If not, it seems better to forego signing such a contract instead of plunging head over into disaster.

Possible further areas of research are finding out how design firms organise megaproject design and how the adaptation processes with regard to the requirements of a specific megaproject are managed.

References

Antoniadis D, Edum-Fotwe F and Thorpe A (2012) "Structuring of project teams and complexity", *Project Perspectives* 2012: 78-85.

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

Brockmann C (2009) "Using cognitive maps for better success in post-disaster relief situations", *Proceedings of the Symposium on Post-disaster Reconstruction*, Surabaya.

Chinyio E and Olomolaiye P (2010) *Construction stakeholder management*, Chichester, Wiley-Blackwell.

Flyvbjerg B, Bruzelius N and Rothengatter W (2003) *Megaprojects and Risk: An Anatomy of Ambition,* Cambridge, Cambridge University Press.

Gidado K (1996) "Project complexity: The focal point of construction production planning", *Construction Management and Economics*, **14**: 213 -225.

Girmscheid G and Brockmann C (2008) "The inherent complexity of large scale engineering projects", *Project Perspectives,* 2008: 22-26.

Glaser B. and Strauss A. (1967) *The Discovery of Grounded Theory: Strategies for Qualitative Research,* New York, Aldine de Gruyter.

Grün O. (2004) *Taming Giant Projects: Management of Multi-Organization Enterprises*, Berlin, Springer.

Hassan S, McCaffer R and Thorpe T (1999) "Emerging Clients' Needs for Large Scale Engineering Projects", *Engineering, Construction and Architectural Management*, **6**: 21–29.

Kähkönen K (2008) "Monitoring degree of complexity in multicultural construction", *Proceedings of the Joint 2008 CIB W065/W075 Symposium*, Heriot Watt University, Edinburgh.

Meuser M and Nagel U (2009) "The expert Interview and Changes in the Production of Knowledge", in Bogner et al. (eds.) *Interviewing Experts,* Houndsmill, Palgrave Macmillan.

Porter E, Neysmith S, Reitsma-Street, M and Baker Collins S (2009) "Reciprocal Peer Interviewing", *International Review of Qualitative Research,* **2**: 291–312.

Sargut G and McGrath R (2011) "Learning to live with complexity", *Harvard Business Review*, **89 (9)**: 68-76.

Spradley J (1979) *The Ethnographic Interview,* Belmont, Wadsworth.

Strauss A and Corbin J (1998) *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory,* 2nd edition, Thousand Oaks, Sage.

Tijhuis W and Fellows R (2012) *Culture in international construction*, Abingdon, Spon Press.

Wilke H (2000) *Systemtheorie I: Grundlagen*, Stuttgart, Lucius & Lucius.

Witzel A and Reiter H (2012) *The Problem-Centred Interview,* London, Sage.