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Hinkley Point C:
The rhetoric and the reality:
Risk and the management of nuclear power projects

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Introduction

In our quest to understand how best to manage projects, Hinkley Point C nuclear power plant stands out as a crucial case study. Currently budgeted at $25bn, although yet to agree final terms to proceed, it is one of the United Kingdom's largest and most risky of projects. It is precisely the kind of mega-project that practitioners and theoreticians have been studying over the last 60 or 70 years to understand how we could deliver major capital investment and societal change better. Currently, it is in a mess. If history is to be our guide, this should be no surprise.

This paper is based on interviews and primary and secondary literature on Hinkley Point C (HPC) and the nuclear power industry. It recounts the historical evolution of nuclear power in the UK, USA and France showing how substantial cost and schedule overruns have been endemic, except in the case of France, largely due to poor technology and quality management. It recounts how public attitudes towards nuclear power of nuclear power has shifted from outright opposition to a position now where the French and British governments see it as central to meeting their Carbon reduction targets, to the extent that today a single nuclear power plant – HPC – is expected to provide 7% of the UK's energy needs once the plant is operating – 13% when combined with its proposed twin, Sizewell C. Only, the plants have to be built first, and on present trends the risks of cost and schedule overruns threaten the whole undertaking. The problems stem from three sources: first, technical difficulties being experienced with the new reactor; second, the financial impact of the resulting overruns on the already stretched suppliers, given the form of contract under which HPC is to be built; and third, the way governance is forcing the go-ahead of the project while ignoring many of the principles of the discipline of managing projects. A persistent question is 'Why is this management knowledge so little heeded on such a crucial project?'

This paper is a case study of not just one very, very large project but of a sector – a sector seemingly coming back from the dead. In describing the issues and events that shape the case, a number of topics are raised that clearly show that we still have difficulty in formulating good practice in the management of projects. The advice offered by theory (the rhetoric) at times fails to address the reality of major project decision-making, often because of parties operating outside the traditional world of project management.

Nuclear Power 1955-2008

Nuclear power has had a continuing relationship with the burgeoning discipline of managing projects since the days of the Manhattan

Project that developed the Atom Bomb around 1942-45 (Groves, 1962; Rhodes, 1986)[1].

UK programs

In 1953 work began on the first (non-commercial) atomic power plants in the UK (Calder Hall) and USA (Shippingsport). The British technology used unenriched uranium, moderated by graphite, cooled by CO2, as the basis of its initial program – Magnox. America used two types of reactor: boiling water (BWR) or pressurized water (hence PWR technology). The UK, which this paper will focus on along with the USA and France, built 26 Magnox reactors between 1957 and 1971, Hinkley Point A being one of the very first. Most plants experienced schedule delays of one to three years.

In 1964 Britain switched, amid considerable unease (on the initiative it is said (Williams, 1980: 259) of politicians facing a General Election), to enriched uranium as the basis of a new Advanced Gas-cooled Reactor (AGR) program. Hinkley Point B was the second AGR to be built. The AGR program was a disaster. Its commercial basis was shambolic (Morris and Hough, 1987: Chapter 6) and it suffered a number of technical problems: the pressure vessel insulation didn't fit properly, corrosion was evident, gas did not circulate evenly,

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[1] Despite a popular belief otherwise, project management was not invented on the Manhattan Project (Lenfe, 2001; Morris, 1994; 2013): at no time did it formally use, develop or refer to any of the tools or techniques now seen as typifying project management, in the way that Atlas, Polaris and other ICBM programs of the 1950s did (Morris, 1994; 2013).

fueling was unsteady (Patterson, 1976). Commercially things were no better: “the financial strength of the consortium, or rather the lack of it, affected the project…partly through the enormous financial and schedule risk, should the consortium [building the plant] fail.” (Morris and Hough, 1987: 113) – a statement which can be applied to Hinkley Point C today without changing a word.

Indeed the whole cast of the management of the plants’ design and construction was technically inept, if ambitious. The program was implemented in two tranches. The ‘sponsor’ organization managing the program, the CEGB – Central Electricity Generating Board – gave considerable thought to how the second tranche could be better managed in light of learnings from the first. Top of the list was avoiding the large number of technical changes that resulted in too many delays and poor site productivity. The Board thus recommended more disciplined management to achieve, *inter alia,* firm control of design, discrete upgrades of technology, stable supply chain relations, and firm price contracting wherever possible with incentives for timely completion. At a more macro level the Board acknowledged that introducing new, untested technology into giant 330 MW production plants was not sensible – it is a form of ‘concurrency’ (Morris, 1994: 124) – and, most creatively of all perhaps, thus extended the target schedule by 50%! (But see EdF’s experience with the European Pressurized Reactor (EPR), below: new, untested technology is forming the core of the new European reactors with massive impact on budget and schedule.) One thing it decided NOT to do was to introduce a formal QA program, even though it had become common practice in the USA by this time. All these points are relevant to Hinkley Point C.

US programs

In America though things were not going particularly better. Unlike Britain the market was huge and purchasing decisions relatively decentralized. The Boiling Water Reactor (BWR) was being sold by General Electric, the Pressurized Water Reactor (PWR) by Westinghouse (but with several other companies becoming involved as demand opened up around the world). US buyers of these reactors were primarily local 'Gas and Electricity' utility companies. Initially the economic case was not compelling: alternative fuels such as fossil (coal, oil, gas) and hydro were available in quantity. Thus to make the economic case more appealing plant size had to grow – from 300 MW in 1962 to 700 MW in 65 to 1150 MW in 1972. From 1965 the market started to grow enormously: from zero plants ordered in 1965 to an average of 29 new plants per year between 1966 and 1974.

Importantly, there was no agency responsible for the management of the sector as an integrated program in either the UK or America. (What was the total demand? How would this be met? What were the risks? Where were the trained engineers to come from?) Indeed, why should there be such a top-down approach to managing the sector? This was [is] a safe, civilian industry: why wouldn't it be managed as say automobiles or computers? You would think that it is too large, too strategic, too dangerous, too critical nationally to be left to firms to offer plants designed, developed and built on an open market basis. Yet, surprisingly this is the institutional *modus operandi* that the industry operates under, as we shall see for Hinkley Point C.

Thus, at the program, meta, level all that FERC, the Federal Energy Regulatory Commission, could offer was regulatory oversight. Direct project management was the responsibility of the utilities. In practice this meant that FERC was constantly playing catch-up, issuing new regulatory requirements ('regulatory ratcheting') which was the cause of much ripping-out and re-work, leading inevitably to cost growth and schedule slippage. GE and Westinghouse ended-up loosing between $800m and $1bn on these (fixed-price) contracts (Mason et al., 1977). But around these issues lie governance practices which to this day shape the way buyers (utilities) engage with suppliers, which in turn directly influence the way that these very large and risky projects are managed, as we shall see.

To make matters worse, the industry experienced an unhealthy number of dangerous incidents, errors and accidents – stretching from cracked piping leading to the temporary shut-down of all BWRs in 1977; siting a plant – Diablo Canyon – on a earthquake fault line; building another – San Onfre – back to front; to installing reactor supports out of plumb. These errors led to loss of confidence and this in turn exacerbated public unease with the technology, resulting in down-right violent opposition in many countries.

France was an exception. Although beginning with eight gas-cooled technology plants it then switched to PWR reactors, building 56 almost identical plants in 15 years, generally with no problems and with outstanding operational performance. Its problems only really began with its involvement with the European Pressure Reactor (EPR) in the last few years. China and Abu Dhabi, among a few others, have followed a similar path – building a sequence of plants as a real program, with minimal variations in design.

The partial melt-down of Three Mile Island (TMI) in 1979 united the two streams of lost confidence – technical error and environmentalist, or community, opposition. In effect it halted the industry's growth: of the 129 nuclear plants that had been approved as of 1979, only 53 were eventually completed. No U.S. nuclear power plant has since been authorized. Chernobyl seven years later provided the *coup de grace.* Fukushima, in 2011, only added to the public's unease over the technology.

Energy options

But the problem is, the world needs a means of generating electricity that has high output capacity, is safe in operation, is not expensive, and is environmentally benign. No single generating technology meets all these requirements but nuclear has the advantage of, in theory at least, most of them being tractable – manageable (*pace* the above). Gas is attractive but may have security of supply problems; coal is dirty – Carbon Capture and Storage (CCS) to clean it is technically not yet possible and is likely to be expensive; solar is insufficient or unreliable in many parts of the world; wind can be socially unpopular; hydro can have damaging environmental impacts and locally inadequate output capacity. And nuclear has waste disposal challenges, and is an inherently dangerous substance. But in terms of the options available, nuclear comes out as one of the most attractive, if only it could be managed effectively. (If we could get a man to the Moon and back, surely we should be able to build an electricity generating plant without the thing going belly-up! An aside made in an off-hand manner but, surely, pointing to a very important observation. Very difficult things can be accomplished – if approached properly.) 1985-2010 (roughly) saw this dilemma – actually ‘trilemma’: reliable capacity, cost, and environmental impact – being argued out.

Climate Change

Cost and reliability have been objectives since for ever. Environmental impact however has developed enormously as an everyday set of objectives since the mid 1980s with the increasingly widespread adoption of various UN authored requirements. The first of these was to mainstream in an operational sense the concept of Sustainability, introduced in its 1987 landmark report *Our Common Future* (Bruntland, 1987). The UN gives 17 separate measures of sustainability, one of which is Climate Change. This is defined as “a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere” (United Nations, website). The prime cause of such change is the emission of Green House Gases (GHG) and by far the most significant of these is Carbon Dioxide (CO2). Decarbonizing the economy became accepted as a responsibility of the UK Government in the 2000s, ultimately via its Climate Change Act of 2008.

While the science, and politics, underlying Climate Change is exceedingly complex its headline objective is extremely simple: limiting the ambient temperature rise above pre-industrial global temperature levels to 2 degrees Celsius. The UN Paris climate negotiations in December 2015 endorsed this goal: 195 countries agreeing on it with the added aspiration of trying to get down to 1.5 degrees Celsius. (Current pledges deliver in total 2.7 degrees Celsius.) For the UK this means that global emissions should peak by 2020 and be halved (or more) by 2050. The 1.5 target is even more ambitious requiring zero emissions between 2030 and 2050 followed by a fall of 3-4% a year.

Nuclear generated electricity emits very little CO_2, even in construction – and virtually nothing in operation – and is thus a powerful means of enabling the UK to meet its GHG emission targets. It should also be a reliable and secure technology. For these reasons it is a key element of the UK Government's energy strategy. But who owns the technology? Who is to build the generating plant? Who is to bear the risks of doing this?

Hinkley Point C

In January 2008, the UK government gave the go-ahead for a new generation of nuclear power stations to be constructed. These were to be built by private sector firms. EdF Energy, Electricité de France's UK subsidiary, was considered for these purposes to be private sector though it is in fact an 85% state-owned French subsidiary the parent of whom had, as we have just seen, been very successful in building France's PWR plants. It acquired British Energy in 2008 and thus became owner of all seven of the UK's then operating nuclear plants. By March 2012 however, after various commercial deals amongst potential suppliers only EdF and Hitachi were left on the scene as realistic players, EdF being the larger and most experienced of the two. But times were changing. EdF was now committed to using new and unproven technology – the European Pressurized Reactor – developed by Areva which the French Government insisted EdF take a stake in as Areva experienced serious financial difficulties.

Meanwhile the UK Government was coming under growing pressure to act quickly to avoid being in breach of its climate change commitments, thus making nuclear even more attractive as a relevant technology. But with a substantial portion of existing nuclear capacity due to be de-commissioned by 2023, this attractiveness was being checked. Negotiations were therefore begun with EdF in 2013.

No other suppliers were invited to bid. It is not clear why not. Perhaps because the bid costs would be very high and the danger of major issues being obfuscated and under-recognized were quite real – as indeed has proved the case at Olkiluoto 3 and Flamanville 3. Partly too no doubt because EdF were the incumbent and had embedded knowledge of the project. But also because the British Government wanted someone who could arrange the financing and building of the plant itself. They were in effect asking EdF, as supplier, to finance the cost of the power station – a form of DBFO – Design-Build-Finance-Operate.

Why was this form of procurement considered appropriate for Hinkley? Partly because this had been the language of the UK nuclear marketplace for some years and the new economic and financial conditions hadn't yet sunk in; partly, as with all such privately financed infrastructure projects, to delay payment, even if the total cost of operation is more expensive.

To assure EdF that the income stream would be sufficient to cover HPC's capital cost the British Government now proposed increasing the strike price to £92.50 per megawatt hour, treble the wholesale price, for a period of 35 years.

Whether this would be sufficient depends, amongst other things, on what the overall capital cost of the plant will be. The omens are not looking good. Historically, as we've seen, the industry has frequently ended-up with overruns due to technical problems. Crucially however, unlike Magnox, the AGRs and the US scene, EdF had avoided this in its French construction programs by using standard designs rolled-out on an almost production line basis. Now EdF was using the new, untested albeit modified PWR, the European Pressurized Reactor (EPR), a considerably more complex product, developed by Framatone, Siemens and EdF/Areva) designed to provide improved safety. The news is not good.

Though untested, it is currently being installed in four plants ahead of HPC. The technical difficulties are real and major and lie at the heart of the instability of the project. As of April 2016:

- The first EPR station is Olkiluoto 3, in Finland: 1600MWe, €3.7bn, 4 year schedule. Begun in August 2005. Technical problems and poor Quality Management have lead to 5 years [forecast] delays [9 years total schedule] and €4.3bn budget increase [€9bn total.]
- The second plant is Flamanville 3, France: 1630MWe, €3.3bn, 4½ year schedule. Construction begun 2007. Technical problems (e.g. welding) have lead to 6½ years construction delays [11 years total schedule] and €7.2bn budget increase
- Plants 3 and 4: Taishan [China]: construction begun 11/09 & 4/10: schedule 46 months – currently +2 years delay

In short, progress to date is dire. Costs have doubled and more. EdF is financially seriously at risk, possibly of bankruptcy. (It already has debts of €37bn. and is embarking on a €51bn. decommissioning program for its first generation PWRs.) From a 'management of projects' 'discipline ' perspective it would therefore seem sensible on these figures alone to revisit the contingency allowances in the capital budget – to use 'reference class forecasting' (Flyvbjerg et al., 2002) and to adopt a cost budget which reflects not just future aspirations but historical reality. (But see below on the challenges of reference class estimating. It is not obvious what the referent group is.) Then, following this review, look hard and realistically at whether additional contingency needs to be added to the schedule, as happened in the second tranche of AGRs. Is more time needed to better test the new technology, as a group of EdF's engineers requested in March 2016? Could the proposed two reactors be built in sequence rather than in parallel? Should a heavier, more formal Quality Management System be installed to prevent much of the 'build' program being threatened, as NASA did for Apollo when faced with the risk of catastrophic failure amidst a collapsed testing schedule (Brooks et al., 1979). (Aerospace in fact makes the point that where the risk of catastrophic failure is high projects can still be delivered safely. There is no reason nuclear power should be allowed to perform any worse.)

Damaging as the threat of cost and schedule overruns is, the real problem area is not so much the schedule but the contract laid upon EdF that would determine how such delays and difficulties should be dealt with. And here the proposed arrangements are very worrying. Given the worsening financial position of EdF and the likelihood of delay and cost growth, the procurement strategy seems back-to-front. Risk is not allocated appropriately.

The British Government wants EdF to finance the capital cost of HPC. It is in effect, as we suggested above, a DBFO with the risk of overruns or performance difficulties lying at the door of EdF, essentially a public sector company. It is in effect a huge and very risky PFI project – a 'Private Finance Initiative' funded piece of infrastructure. But EdF is not now in a position to accept that risk fully. At £18bn and climbing, the cost of HPC may well exceed EdF's market capitalization. Overruns on HPC could bankrupt EdF and leave the UK with a huge energy hole.

Much of the commercial difficulty would diminish if the UK Government, as purchaser, were to pay, in whole or in part, for the plant during its construction. This would radically reduce the risk of EdF going bankrupt with all the waste and disruption (project, program and sectorial) that this would bring. And it would provide a much more reasonable basis of compensation than the high strike rate for selling the plant's electricity output estimated, perforce, in substantial ignorance of what the price of electricity will actually be once the plant goes into operation in a decade or three from now.

Flyvbjerg objects to state financing, arguing that privately funded projects are more realistic in their estimation of risk (Flyvbjerg et al., 2002). The trouble with HPC is that the risk of delays and cost overruns is so large that it would not be acceptable to private sector funders. This only leaves the UK Government, and EdF. (Actually there is another significant player: the China General Nuclear Power Group (CGN) agreed in October 2015 to invest £6bn. in HPC. Their role, current or aspirational, is not clear however and so discussion of its effect on the project is ignored for the time being.)

Sharing of risk between EdF and the UK government would seem more equitable than either party taking the risk wholly, because: (a) in practice the UK Government will have some responsibility for, if limited room to manage, the design or construction risk; (b) EdF should benefit on subsequent sales of EPRs – the increased reward should bring with it the increased risk. With risk more realistically handled, a less drastic, febrile examination of the project schedule could be pursued.

Thus the current financing and procurement model is at best probably unworkable and at worst potentially catastrophically inappropriate. Changing the basis of procurement is therefore key to resolving the jam that the project has got itself into. Once a revised procurement, and financing, model has been agreed then the schedule can, and should, be revised, budgets re-estimated, contingencies reallocated, stricter quality systems installed, interim payment methods devised, and stakeholders reengaged. All this being laid out in a project strategy agreed by both EdF and the UK Government; and with the organizational responsibilities between the project sponsor and the supply team clearly identified. (This may be more hands-on than is usually the case with PFI projects because of the much greater level of risk, uncertainty and contingency.)

All these arguments apply to Sizewell C as well. If EdF finds HPC alone too big a risk, how can it contemplate also financing Sizewell C? Yet somehow this commercial realism doesn't seem to have occupied the minds of the leading actors. Despite the resignation of several leading EdF executives in March/April 2016 including the CFO and the Project Director, senior EdF and French Government officials – notably The President and the Minister of Finance, but not the Energy Minister (actually Mistress), expressed confidence in EPR technology and in EdF's ability to 'manage mega-projects' right until the second quarter of 2016. It seemed that 'optimism bias' was hard at work (Flyvbjerg et al., 2002). However, senior executives and trade union members of the EdF Board pushed back and 'realism bias' began to prevail. As a result, EdF was recapitalized by €7bn in April 2016 and the decision on whether to proceed with the project was postponed until September pending 'widespread consultation'. Its share dropped 11% on the news.

Reflections

This paper was conceived before EdF started to show realism in the planning of HPC. Its belief that all would be alright seemed highly questionable for a project of such risk. Management seemed not to read across from past history the technical difficulties of building such a high-spec plant. The history of nuclear power sends very clear warning signals – signals that have been amply justified in Olkilouoto and Flammanville. Yet these signals appeared not to be being heeded. As the case was being written however, so realism seemed to semi-dawn, albeit with the exception of the contractual roles of EdF and the British Government.

We pride ourselves that capital projects are important vehicles for growth and change in our economies, and that there is a discipline that if followed helps us manage them efficiently and effectively. If this is true, how did the project get into such a mess? Both parties, the procurer and the supplier, are to blame.

- EdF for offering such a complex, risky, untested piece of core technology as the EPR.
- EdF for doing so within its rapidly worsening corporate commercial environment.

- The UK Government for being unrealistic and naïve in accepting such a huge PFI type proposal which is unaffordable as structured and has risk inappropriately allocated but which lets it substantially off any managerial responsibility for the project when problems occur as the country's power supply and climate change targets are threatened.
- EdF for its poor technical and quality management.

Critically, underlying all these factors are governance issues: the sense of hubris and the inappropriateness of the delivery model; decisions made not necessarily in ignorance but rather perhaps in pursuit of different agenda. The lessons in the management of projects as applied internally, so to speak, are well known. But from a total project perspective, which is a feature of 'the management of projects' approach where the project is the unit of analysis (Morris, 1994), it is as if the project's senior sponsors are marching to the beat of a different drum. We have a clash of the politicians' agenda – use of the ERP, HPC as the flagship of French nuclear technology – with the rational, normative professional management model. What we are witnessing are the results of behavioral decision-making where the behaviours are predominantly political.

While there has been strong interest in behavioral decision-making in recent years, both generally and, in projects, about project estimating (Flyvbjerg, 1992), the project work has been largely addressed from the perspective of posited subversive promoters. There is an explicit assumption that 'planners' will not behave rationally but "be driven by the desire to get the plan approved"

Kahneman, (2011: page 250). What we see at HPC is more nuanced: a tussle between political goal setters and practical professionals, with the latter – 'the planners' in Flyvbjerg's terms – in fact offering 'realism bias' while governance is wedded to 'optimism bias'.

There are other issues too, behavioral and non-behavioral, suggested by the HPC case. Take 'reference class' forecasting for example, which we suggested above should be used. Claimed by Kahneman (2011) as "the single most important piece of advice regarding how to increase accuracy in forecasting (ibid.) Step 1 is "identify an appropriate reference class". What is an appropriate reference class for the EPRs? Not ERPs, because there are only four and they have begun so badly. Not French PWRs because they were so different. Possibly not nuclear plants at all, at least not without care. Certainly not some huge group known as 'mega-projects': the characteristics of the sample members vary too greatly. Maybe some mix of all the above, but it requires great care, and caution, in concocting, and using, a valid comparator.

In fact HPC offers many avenues of further enquiry concerning the way engineering, commercial and organizational matters interact with governance at the project front-end stages. Table 1 summarizes some of the more obvious. Table 1 in effect signposts a freshly focused research agenda.

A final reflection is, given how well the history of nuclear power is documented, why do managers seem unwilling or unable to learn from the past? There are several possible reasons but one of the more obvious is because history rarely provides an objective, independent account. Historical truth varies depending on the viewpoint one is adopting (Rublack, 2011). HPC shows clearly how its management has been seen differently from political, technological and implementation perspectives. Bringing out this historical learning can take time and perseverance; acting on it can take even longer.

The real issue though is governance. Overridingly the case poses the question: are we, as researchers and professionals in the field, giving enough attention to building the organizational capabilities (the processes, routines, procedures, roles, standards, etc.) and competencies (individuals' knowledge and abilities) of sponsors and other governance decision-makers so that they can act effectively, drawing on the now rather large body of knowledge that exists on the subject of 'the management of projects'? The answer is almost certainly not.

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Table 1: Principal Outstanding Themes from HPC, May 2016			
Bidding	Why wasn't there competitive bidding?	Too expensive? [But other high value equipment supply industries	Case for a fuller study of procurement in nuclear power

		accept this.]	
Procurement	Why has it taken so long to recognize that PFI is inappropriate for HPC?	Industrial mores [Social science]? Mind-set [Psychology]? Cash flow [Finance?]	This is <u>the</u> key question
Strategy and Policy	Demonstrate the front-end decisions [size, technology, etc.] with config. of EPR and climate change targets.	Decommissioning [expense and timing]; generating capacity targets. Threats arising – energy storage. Support of Chinese.	Upgrade strategy theory: marrying sponsor's corporate strategy and national energy policy with project strategy.
Decision Making	Conflict between professionals and politicians. Effect of schedule pressure. Bias in Estimating	Lobbying and Stakeholder Management. Framing the decision	Bachrach and Baratz (1973)
Technology	What to do when there is a big unproven piece of equipment central to your project?	Off-project prototype testing may be impractical.	Assess risk. Allow adequate contingency. Manage Quality rigorously
Estimating	What 'reference class' group might be used to check the project budget?	Megaprojects are too varied a group, nuclear is too old or special [EPR] – not clear if there really is a referent class group?	Not clear – Finnish, French and Chinese EPRs – but these all have problems [Behavioral Economics.]
Estimating	Is HPC an example of 'realism bias'?	Flyvbjerg's 'optimism bias' is not being supported by the p.m. professionals but is by senior governance	HPC is a catalyst to update this concept.
Risk	Too big to be taken by EdF alone.	Some support from French or UK governments	Risk Allocation

		needed.	
Scheduling	Is parallel construction of EPR possible?		Planning/ scheduling
Power	What to do when poorly conceived instructions are given despite the lessons of history?	Especially important when governance sets up the conditions of failure	Where is the equivalent of a National Audit Office? 'Project Assists?'
Organization-al Learning	Why is EdF not learning?	Because learning is mis-focussed: it needs to be available for Governance, and it isn't. Is EdF learning routinized as well as being drawn from individuals?	Schon: *Reflective Practitioner.* Weick: *Sense Making.* Davies and Brady: *project capabilities*