Routines and Innovation in Engineering Consultancy Services

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In their discussion of the concept of routines as applied to the theoretical framework of evolutionary economics, Nelson and Winter note that the concept applies primarily to organizations that are engaged in the provision of "the same" goods or services over extended periods of time. In their view, organizations such as consulting firms, which can be seen as principally involved in the production or management of economic *change*, do not fit neatly into the routine operation mold (Nelson and Winter, 1982: p. 97). Since the concept of organizational routine clearly imply stability – or even inflexibility – in maintaining existing patterns of production activities, it appears logical to doubt its relevance in sectors that can be expected to engage constantly in change. On the other hand, Nelson and Winter also extends the application of the concept of routines to activities that do target significant change, such as routinized arrangements for producing innovations. These routines are specific heuristics related to search for new organizational routines, and are conceptualized as different from other organizational routines chiefly through their lack of predictability, since they are seen as stochastically generating mutations in organizational routine that can be fed into the evolutionary selection process.

Subsequent research work that has focused on the routine as a search heuristic or learning process also underscores the importance of flexibility and change in the development of these routines. They may be conceptualized as strategic routines, or "change as routine," to be distinguished from operational routines that are merely concerned with the reproduction of the firm (Costello, 2000: 3). Another important conceptual distinction has been made between static and dynamic routines; this distinction contributes to theoretical categories that describe differences in organizational behavior patterns (Dosi et al., 1992: p. 191-93). Static routines form the skills of individuals with the capacity to execute a task or they become the “rules of thumb” that constitute the organizational memory at a higher level of organization. Dynamic routines will be “search capability” at the level of an individual employee or “a capacity for changing routines” at the organizational level (Reynaud, 2000). For evolutionary models of economic change, dynamic routines appears essential for modeling long-term survival of individual firms, since this type of routine will generally define the capabilities for undertaking innovation within the organization. These dynamic routines are attracting more scholarly attention, and Pavitt (2000) have argued that while some innovating routines in business firms remain largely the same, such as those related to coordination and integration of internal knowledge or learning by doing, others related to external knowledge sources or technical experimentation have changed and assumed more importance.

Dynamic routines (or the equivalent “strategic” or “innovative” routines) appear likely to be more significant for knowledge-based consulting firms. If we accept Nelson and Winter’s characterization of consulting activities as primarily devoted to change, and thus difficult to fit into the mould of operational routines, we may instead regard them as particularly innovative. As a group, knowledge-intensive business services have indeed been seen as highly innovative, exhibiting growing technological intensity of production and a high proportion of R&D expenditure and patenting activity (Sundbo, 1998; Metcalfe and Miles, 2000; OECD, 2000). Engineering consultants demonstrate a contradictory case, apparently being atypical on account of the relative absence of operational routines, but still considered innovative. They thus present an interesting case for the understanding the precise implications of routines involving innovative search heuristics. Moreover, consulting engineers have occupied a pivotal role in the creation of industrial societies for more than a century. The engineering consultancy sector has also experienced quite important challenges in recent decades, affecting both the institutional framework of their activities and the technological infrastructure supporting the production of services in the sector.

This paper therefore explores the value of the concept of routine in analyzing innovation in engineering consultancy services. It is organized as follows. First, a brief survey of activities carried out by engineering consultants, the historical development of the industry, and its relationship to other economic or professional sectors will provide a background for exploring various routines in the business. Second, a theoretical framework is proposed that outlines taxonomy of routines and explain their relationship to factors such as institutional change, or new technologies affecting both the production and delivery of services. Third, these theoretical concepts are illustrated with examples from an on-going study of innovation in engineering consultancy firms in Hong Kong. The final section offers some conclusions and conjectures for future research.

1. Engineering Consultants

Engineering consultancy has historically played a key role in the supply of innovative solutions in the design and construction of projects related to infrastructure, buildings, or petrochemical processes. More recently, engineering consultants have become increasingly involved in large-scale planning of public works or infrastructure development, environmental assessment, and even information systems development. The competitive assets of engineering consultancy firms rest firmly on the skills accumulated by their professionals as individuals and in project groups. Internationalization of engineering consultancy services has also followed the growth of transnational enterprises in energy exploitation, manufacturing, and construction in newly industrialized economies. Moreover, an increased utilization of advanced information technology (such as CAD systems) and communication systems has created important opportunities for innovation in the global production and delivery of engineering services (Baark, 1999).

The core competence of engineering consultants is their ability to apply scientific and technical knowledge - mostly in a combined form of technical calculations and tacit knowledge of design based on extensive experience - to a project of construction. To a large extent, however, these resources of the engineering consulting business are also deeply embedded in institutions that foster or regulate the market for technical knowledge. Such institutions include a number of characteristics that are particular to professional services, which have traditionally been based on trust and reputation (Aharoni, 2000). The engineering consultants operate in an environment where the quality (or price) of services can be difficult to assess *ex ante,* and where the production of services increasingly involves the accumulation and implementation of very sophisticated technological knowledge, often with the assistance of computerized information systems.

The fundamental characteristic of engineering consultants' work is the use of a unique body of knowledge to provide a particular range of services relating to the design and construction of projects – to use the terminology of Teece et al. (1997), the competitiveness of a firm is firmly based on its knowledge resources. Most consultants have emerged from the civil engineering field, partly on account of a tradition in both public and private construction projects for the owners of the project to outsource significant components of design and supervision to civil engineering professionals. In the mechanical, chemical, and electronic engineering fields, by contrast, major corporations have tended to maintain large contingents of engineering staff in-house (Sinclair, 1988, Mowery and Rosenberg, 1989). Clients of engineering consultants – frequently called "project owners" or "project promoters" – would purchase services ranging from a study of the technical feasibility of the project to the supervision of the actual construction according to detailed specifications. These services comprise reports, design specifications, and other forms of assistance, all of which basically embody advanced technical knowledge, as an aid to clients in their decision-making process. Although a growing number of engineering consultancy firms in advanced industrialized countries have diversified recently, their core activities continue to be services directly related to construction.

To a large extent, the real competitive assets of engineering consultancy firms are thus contingent on the quality and capabilities of their human resources. These resources are usually organized in project teams led by certified engineers with a long-term experience in specialized areas of engineering. Such human resources embody the tacit knowledge as well as the stock of formal knowledge accumulated in the organization. They bring this knowledge into practice by applying it to the feasibility study and evaluation of a project, various phases of design, and in the supervision of project implementation. Engineering consultants are usually engaged in providing services for the first phases of the project cycle, from the initial phase of identification and feasibility study up until the commissioning of a structure or a manufacturing plant. For the clients, support from engineering consultants is frequently needed in order to ensure the quality and efficiency of technology applied in construction projects. Decisions made during the design phase of a project will have very significant economic consequences during its implementation. Costs of construction saved through a resource-efficient design that optimizes the use of input materials such as concrete will often correspond to a multiple of the cost incurred in producing the design.

The engineering consultancy industry in the industrialized countries has typically consisted of a very large number of small firms serving a local market, and a rather small group of large firms that are undertaking large projects at home and abroad. In the immediate post-war period, a single person or a partnership owned many such small engineering consultancy firms in the US, but during the 1970s, a great number of these small firms became incorporated. These have formed the backbone of a group of US design firms which continues to dominate the industry. Many of the firms that were first surveyed by the leading trade journal *Engineering News Record (ENR)* in 1965 are still listed high on the Top 500 list published today ("Industry Stalwarts Still Practice", *ENR* April 3, 1995, p. 42.). This serves as an indication of a relatively stable long-term market demand, in spite of the fact that cycles in turnover for engineering consulting firms tend to follow the variations in construction business closely, which in turn depend on expansion or recession in economic growth patterns.

Engineering consultancy is very closely associated with the construction, in some countries to an extent that it becomes difficult to differentiate these two industries accurately. There is a trend that the work of "pure" engineering consultancy firms are getting increasingly integrated with construction. The extent to which engineering design is purchased from specialized firms or is integrated in public or private firms undertaking construction projects is thus often a matter of national traditions. In Italy and France, there is a tradition for integrated departments carrying out design (i.e. captive engineering design units in major contractor firms). The British system of engineering services procurement has placed more emphasis on the independence of engineering consultants, and to some extent the United States has followed a similar institutional trajectory.

Large engineering construction firms have, for a long time, regarded their ability to undertake major projects from the beginning to the end as one of their main competitive assets. This trend may blur the distinction between design and construction. It may also be partly responsible for the tendency to rely increasingly on joint ventures and consortia for international projects. The trend towards "design-build" coalitions is also affecting medium-sized and even smaller design firms, which are encouraged to enter into partnering arrangements with contractors. In many cases, the demands from owners of projects constitute the key driving forces forcing engineering design firms to diversify in terms of project work partnering or new areas of business. Changes in project management and procurement, which are intended to capture economic efficiencies by transformations of the relations between different parties in construction such as design-build or partnering, may ultimately affect innovation adversely (Miozzo and Ivory, 2000).

2. Service Innovation and Routines: Some Theoretical Issues

Although the contribution of innovation in services has been underscored by recent statistical data (OECD, 2000), the nature of innovation processes, their driving forces, and effects for those services has remained elusive. From a theoretical point of view, the pattern of innovation involves a diversity representing a spectrum of “innovation modes” at least as complex as the taxonomy proposed by Pavitt (1984). Soete and Miozzo (1989) have suggested taxonomy of innovation modes in services that focus primarily on differences between reliance on internal and external sources of innovation. In their scheme, the first category of “supplier-dominated” services include personal services and social services where firms rely almost entirely on external sources of technology. A second category of “scale-intensive” services encompass firms which operate networks such as telecommunications or air transport, and a large group of service industries dependent on large-scale networks such as financial services. Firms in this category tend to employ a mix of external and internal sources of innovation, having become engaged in large-scale and risky investments in new technological systems during recent decades. Finally, a third category of "science-based, specialized suppliers" depend almost entirely on technology innovation within the firm, and knowledge possessed by these firms often constitutes their fundamental competitive asset. Consultants are usually mentioned as examples of the third category, although the concrete nature and source of their innovations have not been studied in detail hitherto – at least not to my knowledge.

Actually, to determine the extent of innovation taking place in the engineering consulting industry appears less straightforward than what one would intuitively assume. It can be argued that every new design or construction project involves innovative elements such as the adaptation of existing technology to local conditions, or unique combinations of technical components. The word "engineer" suggests deep roots in creativity, as the Latin origins *ingeniare* means "to contrive," implying the invention or creation of new things or methods. *Ingeniare* was a word initially applied to Roman military inventions and the role of engineers were largely military up until the civil engineer became prominent in the construction of infrastructure and other works during the industrial revolution. Self-reflective modern engineers, such as Samuel C. Florman (1987), have emphasized that creativity is necessary in producing engineering design, and that this creative work is often appreciated as emotionally fulfilling and satisfying. Henry Petroski (1985) argues that design is more than the rote application of scientific formula, and indeed, may resemble the production of art with many elements of re-combination of existing knowledge and iterative trial-and-error processes. An introductory textbook (Wright, 1989: p. 95) describes the work of engineers in the following terms:

> The nature of problems that must be solved by engineers varies both between and among the various branches of engineering. Indeed, an individual engineer may face a variety of problems during the course of his or her daily work activities. Because of the variability of engineering designs, there is no definitive procedure or list of steps that will always fit the engineering problems at hand. However, engineers tend to deal with problems in a special way. Certainly, the engineering method of approaching and solving problems differs greatly from that of most other professionals. Engineers are trained to think in analytical and objective terms and to approach problems methodologically and systematically.

Nevertheless, both education curricula and practical work experience in engineering provide much less emphasis on creativity than does a closely related field such as architecture. Typical civil engineering design emphasize the importance of application of available know-how and standards, a requirement that will often constrain the pursuit of an entirely new and revolutionary design. Professionals in the business will often be quick to point out that civil engineering is a very old field of engineering (viz., the pyramids), and that many of the established approaches to structural analysis have remained the same for a long time. Moreover, one of the hallmarks of civil engineering is a great concern with safety and the risk of product, structure, facility, or system failure. For this reason, decisions made during the design process will often seek to avoid innovation if known solutions cannot be repeated or adapted (Wearne, 1993: p. 21-22).

New services are not normally developed without a market demand that is clearly articulated, for instance, by way of client's requirements for a proposed new project. One study of the Canadian consulting engineering industry found that the process of innovation "is one of quiet and subtle change. Often, it consists of visiting a plant designed and constructed years earlier and observing how the client/owner has altered the process and design for better use. On the other hand, innovation is not always desired. For some projects, particularly those demanded by the government client, innovation is actively discouraged." (Hammes, 1988: p. 40)

In other words, industry observers appear to agree that a certain degree of creativity and innovation is required in performing the routines that engineering consultants employ in their work, but that these innovations will mostly be incremental, informal, and deeply embedded in project work routines. Many innovations are incremental in the sense that they do not, in general, present radically different solutions or require substantial changes in production processes. Engineering consultants are professionally required to be extremely conscious about the feasibility of various alternative solutions to a problem. The majority of innovations in design will emerge during the initial phases of the project cycle, that is, as part of the analysis of project feasibility study, evaluation of alternative solutions, and conceptual design. Some large engineering consultancy firms operate R&D departments to provide formal technical support for new innovation, but in the vast majority of firms, innovative ideas are launched and tested in the informal context of the project team. Incremental and informal innovation is characteristic of service sectors, but such features tend to create conceptual confusion and make it especially hard to distinguish clearly between operational (or static) routines and innovative (or dynamic) routines. Engineers will typically search for optimal solutions as part of their operational routines and frequently adjust the design – or evaluate alternative solutions – in the process of meeting the requirements of the project. To the extent that innovative routines can be identified, they appear to relate to decisions made very early in the planning of a project, or they constitute an attempt to streamline operations or pursue new business opportunities. These activities can be conceptualized as routines insofar as they follow a search heuristic aimed at the identification of a new solution, hitherto ignored, for a problem for which the operational routines have failed to generate a satisfactory result. They overlap with organizational and management routines, usually undertaken by senior partners, which seek to explore and exploit new business opportunities. But they are seldom regarded as "innovative" by the engineers themselves.

In order to distinguish innovative routines from the mundane operational, static routines in engineering consultancy firms I propose to focus on three major categories of innovations: new *products* (services related to design, specifications, data, etc. for a project); new *processes* (a change in the way that such services are produced); and new *delivery methods* (a change in supplier-client interaction). Most engineering consultants recognize the importance of product innovation since the reputation of firms will often depend on the extent to which they can document the provision of new services, resulting in a new and better design, supervision management, or construction methods. Projects boasting ingenious design or skillful use of new materials also dominate the pages of the trade journals, and the vast majority of innovations reported relate to new structures, new software, or similar products. Process innovation is generally not acknowledged to the same extent as the more tangible product innovations by professionals, since much of the production of services appear idiosyncratic and/or shaped by the relationship with clients. Nevertheless, with the widespread adoption of information and communication technologies (ICT) processes of work organization, project group coordination, and work responsibilities (viz., the virtual disappearance of draughtsman) have arguably been changing rapidly - and perhaps in even more substantial ways than products - for the engineering consultants. Delivery innovations are also motivated by the application of ICT, for instance, in the form of electronic tendering, and by the pressing need for further integration of the design and construction processes. Innovations in delivery are particularly important in service industries (Miles, 1995), and the changes affecting consulting engineers in this area may have important implications for future competitiveness.

Routinized arrangements for producing innovations are different from operational routines in terms of the nature of the results - more specifically the unpredictable nature of the result (Nelson and Winter, 1982: 132). This implies that a higher level of risk taking will be associated with innovative routines. However, from the perspective of empirical research it is difficult to assess the element of risk and uncertainty - both *ex ante* and *ex post*. Therefore, I would propose to examine routines associated with innovations, as differentiated from operational routines, on the basis of three additional criteria: (a) trigger mechanism; (b) knowledge sources; and (c) explicit/tacit knowledge. The concept of trigger mechanism describes the events that lead the organization to initiate the routine. For routines associated with innovations Nelson and Winter suggest that the event will often be a puzzle or crisis in the deployment of existing operational routines, while operational routines are triggered by the opposite - a recognition of a known solution to the problem at hand. In addition, I would argue, many innovative routines are initialized by new demands from the environment (e.g., clients), or by the awareness of new opportunities, which may or may not be related to existing routines. The sources of knowledge mobilized for innovation are likely to be qualitatively different, both in the sense of location (outside organization rather than inside) and in terms of status (not "common" knowledge); I would expect it to be so even if existing, reliable operational routines contribute important building blocks to innovation (Nelson and Winter, 1982: p. 131). One of the key difficulties of exploring innovative routines in engineering consultancy empirically is the prevalence of tacit knowledge, and the role of intuitive judgments based on past experience and flexibility in handling complex systems, which so characterize the evaluation and development of new designs or project operations in the sector. Operational routines are expected, to a much larger degree, to involve explicit, "textbook engineering" approaches.

Moreover, innovations will be contingent on a wide variety of institutional factors, including relevant regulations, scope and nature of contract relationships, and the market for technical services. These factors represent external drivers or constraints for innovation in services that, to a large degree, must be conceptualized as an interaction process (Sundbo and Gallouj, 2000). The accumulation and application of knowledge in engineering consultancy is deeply embedded in the historical and national characteristics of the sector, together with the complex institutional framework of the production and delivery of engineering services. Innovation in the sector reflects all of these aspects, and the contingency of innovative routines on existing institutions must be addressed. I propose to discuss the following items below: (a) the relationship with clients and contractors, (b) the role of regulations and quality standards, and (c) procurement procedures. The institutions of client and contractor relationships for engineering consultants have evolved over many years, but as mentioned earlier in this paper, they are currently under transformation because the market promotes more integration and coordination in new projects (Hartley, 2000). Regulations and standards remain essential for civil engineering works, but recent decades have witnessed additional emphasis on safety and environmental concerns, together with a demand for quality assurance inspired by the ISO9000 certification process. The dominant patterns of procurement will also shape innovation in the sector, in particular because the relative emphasis that public or private clients place on technical excellence/innovative solutions versus cost/price considerations will determine the extent to which engineering consultants feel encouraged to venture into new approaches.

New opportunities and demand for innovative approaches in engineering is fundamentally shaped by the diffusion of powerful information and communication technologies. This is the case, in particular, with process and delivery innovations. ICT has also opened up new opportunities for management of coordination and control in engineering consultancy projects, with additional potential for innovation. So far the effect on engineering consultancy firms has followed influential theory the "reverse product cycle" proposed by Barras (1986): first, information technology has been employed to aid the production of design (with CAD systems) and assist communication in projects (with fax and email); second, digitized data and advanced database management software (such as Geographical Information Systems - GIS) have enabled engineers to offer new services; third, integration of systems internal and external to the firm, or in global networks (such as the Internet), provide a platform for other service products and delivery innovations. Gradually, these new opportunities have come to provide the key stage for competitive strategies among the largest consultancy firms, and innovative routines need to be developed that can explore possibilities for such firms to generate new processes or products.

To sum up, the assumed importance of indigenous innovation in a knowledge-based service industry such as engineering consulting contrasts with the perceptions of many industry practitioners and some outside observers, who tend to characterize the search for new solutions as integral to operational procedures and mostly of incremental nature. These observations accentuate the theoretical and conceptual difficulties of identifying what exactly constitutes innovation, and to what extent innovative routines can be clearly distinguished from operational routine in the business. Nevertheless, I have proposed that innovations can be identified for products, processes and delivery, and that the innovative routines which are related to these may be characterized in terms of trigger mechanisms, knowledge sources and the composition of explicit/tacit knowledge. In order to understand the factors which shape these innovative routines, I propose to examine the institutional context, more specifically focusing on three institutional factors, namely: the consultant's relationship with clients and contractors, the role of regulations and quality standards, and the procurement procedures. Finally, I shall discuss the influence of ICT in shaping innovation and innovative routines in the sector.

3. Innovation in Engineering Consulting Firms in Hong Kong

This section reports some observations related to innovation and routines in engineering consulting firms in Hong Kong. It is based on the results of 15 structured interviews with representatives from the firms, carried out during the period October 2000 to May 2001. The majority of the representatives were managing directors and/or chartered engineers in leading positions with respect to project identification and implementation. The sample include local offices of overseas engineering consulting firms, with relatively large staff (500-700 local employees), and several consulting firms based primarily in Hong Kong, usually with a number of staff in the range of 100-400.

Hong Kong has been a major market for engineering consultancy services in Asia for several decades, culminating in the Airport Core Projects (ACP) during the 1990s. The ACP involved design and construction of a world-class new airport at Chek Lap Kok and associated infrastructure at a total project cost of US$ 20 billion. Major projects undertaken by the public sector has thus provided an attractive market for engineering services. Moreover, the sector has gradually witnessed more competition as new procurement and tendering approaches have been introduced, combined with the effect of new entrants in a stagnating market. Although major infrastructure projects still call for highly specialized expertise that only overseas firms are able to provide, the Hong Kong offices of major consultants currently command sufficient resources to undertake most projects. In fact, the Hong Kong offices of firms like Maunsell and Ove Arup are now the largest in these globally networked firms. These offices primarily draw new staff from Hong Kong and function quite independently, or act as regional headquarters (Baark and Ma, 2000).

The level of technical competence in most of the engineering consultancy firms operating in Hong Kong is similar to international levels, though services for some specialties may have to rely on foreign expert inputs. Innovations peculiar to Hong Kong can be witnessed in areas such as water reservoir design, land reclamation, building construction under severe constraints (for example, construction of high-rise buildings on steep slopes at the mid-levels of Hong Kong Island), and extensive use of high strength concrete for high-rise buildings. However, many new designs or construction methods are based on techniques developed elsewhere in the world and then adapted to Hong Kong conditions. In terms of innovations in work processes and delivery based on new ICT, many Hong Kong firms may be lagging behind US or European competitors by a several years, but quite a few appear to have utilized advanced facilities to generate innovative services. In other words, the engineering consulting sector in Hong Kong is sufficiently advanced to provide a fertile ground for investigating the extent and role of innovation.

Many of the engineers interviewed in Hong Kong firms expressed doubts about the extent and role of innovation in the sector. On the one hand, their perspectives provide a good illustration of the difficulties of defining what innovation is - or is considered to be - in the sector. On the other hand, the interviews have indicated the extent to which innovation is considered to be crucially important for the competitiveness of firms. Several interviewees indicated that most of what they did would not be considered innovations. One engineer was adamant on this point, insisting that the provision of new services, or the use of IT to improve service delivery, merely constitute good business practices:

> What services we provide relate to the way our business is conducted. You ask me if we use Internet to deliver our services, this is the technology that we use in our business. This has nothing to do with innovation. When we do an electrical design, we can use actual drawings as deliverables or we can use electronic version of it as deliverables. What are the relationships between the way we do things and business innovations? .... Data and information being transmitted through electronic means are very common. Obviously any firms that need to survive have to gear up for this new mode of IT. We have to change our computers every 2 to 3 years because they are just too slow. These are the changes technological development has brought about. But this doesn't really have anything to do with innovations! (Interview no. 1, March 29, 2001)

The respondent belongs to an international firm that is generally considered innovative, and he would readily acknowledge the importance of innovation while at the same time maintaining that most of the activities (i.e., routines) were just "normal business." Another respondent linked innovation closely with formal R&D aimed at creating new design, and consequently argued that competition had inhibited the process of innovation in the sector (Interview no. 3; March 30, 2001):

> I think consulting engineers have been innovative, probably more so in the past than they are now. All the problems we've got is that the way things are going in Hong Kong and most of the rest of the world to a degree [is that] we've gone very much to be competitive. To some extent, we can afford to do less research and development which is really what you need to put some resources into in order to be able to develop ideas. Because people can have ideas, but someone's got to be prepared to allow them to develop that to a degree, and that costs money.

Most respondents in the industry associate innovation with "ideas" for a new design or material, revealing a clear bias towards product innovation and "tangible" output of the innovation process. Several firms had set up procedures to encourage innovation from that perspective, holding competitions for innovation awards that would provide the winner(s) with additional financial resources to pursue the development and testing of their "idea." Moreover, it was common practice in the engineering consultancy firms to hold brainstorming sessions in relation to major new projects. These sessions would often be aimed at mixing junior and senior staff to encourage an atmosphere of creativity with respect to formulating possible solutions, but at the same time ensure that "ideas" were thoroughly vetted by senior engineers with enough experience to assess the feasibility of proposed innovations. This type of heuristic procedure clearly exhibits the characteristics of a problem-oriented search, usually induced by the demands of a new project. Some of the firms that emphasized advanced applications of ICT also indicated that senior management would be involved in evaluating the potential for developing new services or internal tools to enhance productivity, but these routines were seldom formalized.

Trigger mechanisms for routines aimed at product innovations were generally associated with clients' demands, and delivery innovations also appeared to originate in external demands. For process innovations, the factors inducing a search for new ways of organizing or cooperating on projects are usually related to attempts to save manpower, either in the form of the costs of employing specialized expertise or simply by compensating for lower fees (as a result of a more competitive tendering procedure). But many respondents emphasized that they would not normally be looking for new ways to innovate if there were no immediate purpose. One respondent pointed up this principle in these terms (Interview 4; March 30, 2001):

> I couldn't think of anything, actually, that I could offer to build where the world has not seen it before or the world don't know it before. Engineers, we are distinguished from scientists in a sense that I think we apply scientific principles to achieve practical results. There must always be a product, perception of a product, by a developer to start the process. We don't go dream up something and then knock on the developers' door saying maybe you want to build that. It's not our business.

Engineering consultants in Hong Kong relied extensively on sources of knowledge for innovation that were external to the local office. For quite a few cases of innovation in service products, consultants would introduce knowledge available from other offices in the firm or from public research. Even for many process innovations, the basic knowledge for a new organization or pattern of work is likely to be available in some form elsewhere, and would be introduced in Hong Kong as a result of collaboration with partners, etc. Sometimes, the knowledge required for incremental process innovations introduced by Hong Kong offices will be embodied in software adopted as part of a project.

For product innovations, much of the knowledge mobilized as part of an innovative routine is tacit - relying on extensive experience of senior engineers. It is evident that engineering consultants accumulate knowledge over extended periods of time and as a result of exposure to "real life problems" in construction sites (which is one important reason that the qualifications for chartered engineers includes several years "in the field"). Our interviewees agreed that product innovations were predominantly based on the inputs of senior staff, even if they acknowledged the need to encourage junior engineers to put forward their ideas. Tacit knowledge regarding the feasibility of various solutions was a key component of the vetting process involved in the heuristic of innovative routines. At the same time, process and delivery innovations appeared to require the formalization of knowledge inputs. This was mostly because these innovations were so intimately tied up with the increased use of ICT. For example, a new routine to account for billing of project work involved the development of two-dimensional bar codes to keep track of each engineer's work (interview no. 11; May 10, 2001):

> Basically because we are trying to keep track of time, try to automate our time sheets, right now we submit timesheets every week. We just key in an excel file.

> The excel file will go into the system and convert all the number into the 2-D bar code system, with your name and all the jobs, job number, date you are working on that. All the information is stored using the bar code. When you get the time sheet signed by the supervisor. The time sheet will go to the accountant. They just scan it in and it goes to the accounting system automatically and all the billing will come up right away. Not like before, you would spend weeks trying to collect those time sheets and enter them by hand.

A similar tendency to promote explicit statement of the information or knowledge applied by the engineers can be observed in the digitization of design and calculations/simulations with CAD systems and software, which enables engineers to exchange drawings and to work on different aspects of the same design concurrently.

I have already alluded to the key importance of client relationships as part of innovative routines in engineering consultancy firms. One respondent (interview no. 19; May 31, 2001) half-jokingly summarized this with the statement: "Here in Hong Kong the client is God!" Clients thus have a significant role in determining the fate of an innovative idea. Various government departments may have different views on innovation, some receptive to new approaches and others decidedly known for their resistance to change. In general the Architectural Services Department and the Works Department were regarded as flexible and willing to support innovation, while the Housing Authority or the Water Works Department were known as extremely conservative and much less interested in innovative approaches or designs. In addition, contractors can influence innovative design. However, it is a relatively recent phenomenon for engineering consultants in

Hong Kong to be very concerned with the "constructability" of design and to interact intensively with contractors to ensure that their design can be implemented during construction. The primary vehicle for this type of innovative cooperation routines has design-build or partnering arrangements; however, these have only gradually gained ground in Hong Kong during the last decade and many people see the problems afflicting the construction sector as the result of antagonistic relations among the parties involved in a construction project.

The second institutional factor that has clear implications for innovative routines among Hong Kong consulting engineers is the existence of a comprehensive framework of regulations and standards. Several interviewees stressed the inhibiting effect of building codes and similar detailed regulations, which often generate important obstacles to innovation. Standards are important for all kinds of building design, as they serve to maintain acceptable levels of safety, etc. This fact is obviously recognized by the engineers, and the need to observe standards and codes is normally regarded as an inherent constraint in producing a design. Nevertheless, standards and codes tend to be conservative, and occasionally innovation in design or materials require an updating of current standards. The Hong Kong Government then has to be persuaded that the innovation is useful and does not entail any new risks, and engineering consultants frequently experienced the process of convincing government officials cumbersome. One interviewee expressed it this way (interview no. 1; March 29, 2001):

> For example one of our projects in Times Square. Times Square was one of the first projects in Hong Kong where we can use composite steel deck as a structural

> element. In the past the Hong Kong government has been quite conservative. They would not allow you, in the building regulations, to use composite steel deck as a permanent element. They only accept it as a temporary form works as such. For that project, we went up to see the Buildings [Department] chief and explain to him this kind of usage has been used in North America and in Europe for the past 30 years. They have done a lot research which would enable you to trust the product and to trust the design. ... we had to submit a lot of reports to them, and we go through all the trouble and then they allowed us to use the composite steel deck.

With the tight project schedules that are common in engineering consulting projects, the time and other resources spent in persuading government officials are too precious to set aside, so for these kinds of innovations clients also have to be quite patient and enthusiastic about the new design.

Quality assurance along the lines of the ISO 9000 standard has become essential for engineering consulting in Hong Kong, and certification is essential for winning public works contracts. In general, innovation is enhanced by the considerations of quality assurance, and the search for the highest quality solution to technical problems has been incorporated in all aspects of the work of excellent engineers for a long time. Firms have practiced various routines for double-checking designs and ensure optimal solutions for a long time, and the most important new innovation has in fact been the ability to use electronic transfer of design drawings, etc. overseas for additional checking by specialists. Our interviewees recognized quality as one of the key determinants of their competitiveness, and regarded routines to assure quality as essential for the business. However, some interviewees complained that quality assurance procedures often detoriated to extensive formalized paper-work, losing sight of the original purpose. In particular, the time-consuming procedures for quality assurance during project implementation imposed by some government departments were regarded as obstacles to creative work.

One of the most important changes shaping work by engineering consultants in Hong Kong during the last decade has been the introduction of a more competitive, two-envelope procurement system for public projects. This system is designed to allow the client to focus on the technical quality and feasibility of individual bids, and subsequently choose the least expensive of equally technically excellent bids. It is usually practiced with some sort of quantitative score for technical excellence (often including a component of the score, 5-10 points out of 100, for innovativeness) combined with score for the cost of fees. If the weight of scores maintains a ratio of 80:20 for technical/cost aspects, the system will generally support competition on technical excellence and innovative solutions. If the ratio is around 50:50, as has become the practice for some government clients in Hong Kong, price competition becomes rampant, and many engineering consulting firms will feel had pressed to pursue innovative designs. As one interviewee summed up (interview no. 6; April 6, 2001):

> ... the price the government is paying for engineering consultancy work is reduced by about 50% in the last 4 years. Despite its insistence to the contrary, that means, fundamentally, the level of effort that goes into design is less. That means

> they are more likely to copy what they did last time or what's been done elsewhere, which means they are less and less likely to innovate. Unfortunately. That's bad for the profession and it's also bad for the community.

However, while the competition on fees tend to reduce the scope for product innovation among engineering consultants, it will tend to induce process innovation at the same time. Basically, the competitive environment implies that consultants have to achieve the same output with fewer resources, and this encourages attempts to streamline project work, cut labor costs, and increase the productivity using advanced information technology.

> When you go and try to bid for a job, it's so competitive, too many consultants. The profit margin gets less and less. It's a fact now. Only way we can do is to improve our efficiency, so our company has set up an incentive right now, we would like to have IT help us to run the job, to make ourselves more efficient, say, take 10% off the costs, that's 10% profit already. So, in the next few years, we will be trying to use IT to make ourselves running more efficiently and try to streamline our process in terms of designs, starting at the feasibility study stage, to the design stage or even the site supervision stage. There'll be a lot of web applications help you to send out progress report, developing reports (interview no. 11; May 10, 2001).

Some additional signs of this change can also be seen in the transfer of detailed design work to offices in the Chinese Mainland, such as the Shenzhen special economic zone, where the cost of employing a competent engineer is lower than in Hong Kong. Nevertheless, most engineering consultancy firms in Hong Kong have been reluctant to reduce their professional staff drastically, instead seeking diversification into new business opportunities that could employ the existing staff to a higher degree.

Finally, information technology has become a decisive factor with regard to the possibilities for product and process innovation in engineering consultancy. In Hong Kong firms, innovative routines exploiting ICT for the development of new products and processes have started to take root during the last 5-10 years. Many new services offered have been derived from the extended use of advanced databases, geographical information systems (GIS), remote sensing, or even global positioning systems (GPS) in consultancy projects. For example, a project that recently won an innovation award in Hong Kong is a program called CLASH which is actually a three dimensional representation of how the utilities are laid out under the airport runway. Tools of this kind have been existed for a long time in oil refinery constructions, but CLASH was adapted in an innovative manner to the problems of coordination in a major infrastructure project such as the airport. The increased sophistication of GIS systems utilized in engineering consultancy supports both product and delivery innovations. Computer-generated simulations can provide important assistance in presentation of the results of studies (interview no. 11; May 10, 2001):

> In Hong Kong, they still prefer face-to-face [presentations] but, I mean, what we save here is we don’t need the specialists to come in. The project manager has to go to talk to the clients, but when we are showing, like the good IT stuff, they are impressed. Before they have to read 5 chapters to know what’s going on. Right

> now, we just show them one helicopter ride. This is what we want, this is what we have decided, this is what we have. Bang, there it is.

An important precondition for a dedicated search for innovative exploitation of the potential offered by ICT is, according to our interviewees, the existence of a supportive culture for innovation in the firm. It is hard to maintain this culture on account of the short-term cost considerations that fee competition and a stagnating market for engineering services in Hong Kong has generated. Another issue related to creating and maintaining an innovative culture is the educational background and qualifications of junior engineers recruited in Hong Kong. Several interviewees complained that creativity was not instilled to a sufficient degree in secondary and higher education institutions in Hong Kong, making it less easy for the engineering consultancy firms to groom new recruits in innovative approaches. Therefore, many of the leading firms emphasized recruitment of engineers trained abroad.

4. Conclusions and Conjectures

In this paper, I have sought to throw new light on the usefulness of various concepts of routines in analyzing innovation in the field of engineering consultancy. One of the problems that emerge is to conceptually distinguish clearly between operational routines and innovative routines. Although the character of routines related to innovation can be theoretically defined in terms of more flexible heuristics (not as "mechanical" or procedural as for operational routines) and the unpredictability of results, these characteristics can be difficult to relate to the empirical reality. For engineering consultants, these problems of demarcating "innovative" routines appear to be particularly complicated. My research into innovation in engineering consultancy firms in Hong Kong illustrates that engineers themselves have difficulty classifying some routines as innovative (and accordingly, other routines as not involving innovation or creativity), a problem that they probably share with engineers elsewhere in the world. As an outside observer, however, it is still possible to identify some routines related to innovation. These routines tend to be different for product, process or delivery innovations, and I have outlined some of the areas in which they differ. However, a common feature of innovative routines is that they are contingent on the institutional context of engineering consultancy business and, in particular, on the effects of widespread use of information and communication technologies. In fact, process innovations associated with these technologies are likely to lead to transformation of work organization and potential new services that may emerge as key competitive assets for engineering consultancy firms in the future.

It is interesting to note, however, that many practitioners and managers in the sector still tend to focus on product innovation (e.g., new design). They may not yet be sufficiently aware of the need to foster innovative routines capturing process and delivery innovation opportunities; although in fairness it must be acknowledged that several of the people we have interviewed were deeply engaged in strengthening their firm's capabilities in these areas. One of the important research tasks that thus emerge out of this project is to develop a better understanding of such innovative routines.

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