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## **Building Global Engineering Network Capabilities**

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### **Abstract:**

Network issues are increasingly concerned in operations management domains. But a generic understanding of essential network capabilities for global operations is missing. How to build network capabilities in changing business environments is also poorly understood in the existing literature.

This paper presents essential network capabilities for global operations through in-depth case studies focusing on engineering operations and demonstrates how to build the capabilities with a network configuration approach. The cases were deliberately selected to represent a breath of network operations from the perspectives of industry sectors, scale of operations and the nature of products and production systems.

This paper improves the theoretical understanding of network capabilities for global operations from an engineering perspective. Evidenced by pilot applications, this research can help companies to improve the performance of their global network operations through consistently aligning network capabilities with main business goals in changing environments.

**Key Words:** Global Network Operations, Network Capabilities, Global Engineering Networks (GEN)

## **1. Background and Introduction**

Network issues have been increasingly concerned in operations management domains driven by the dispersion of business activities across national and organisational boundaries. The traditional network theories explained why network actors with diverse motivations forge enduring relationships from economic (Grabher & Powell 2004), sociological (Podolny & Page 1998), or organisational perspectives (Powell 1990; Snow, et al. 1992) without providing a systematic view of how to design and operate global networks with certain capability orientations. The existing studies on organisational capabilities were developed with little concern of the particular requirements of network operations (Prahalad & Hamel 1990; Grant 1991; Leonard-Barton 1992; Teece, et al. 1997; Javidan 1998; Barney 1999; Eisenhardt & Martin 2000; Winter 2003). How to build appropriate capabilities for global network operations is poorly understood in the existing literature in contrast to its apparent importance for supporting global markets, assessing global resources, or improving global efficiency (Dunning 1993; Dicken 2003).

An improved understanding of network capabilities for global engineering operations is particularly important for practical and theoretical reasons. The practical importance stems from the intangible nature of engineering, the globalisation of engineering operations, and the emerging tools and techniques to complete engineering tasks (Zhang, et al. 2008). It is often challenging to manage dispersed engineering activities among functional teams in a factory, but now these activities have to be managed on a global scale. Investigations into global engineering network capabilities will also lead to a significant theoretical contribution. The traditional view of engineering capabilities was built on a rather simple assumption of stable environments. The recent literature addressed issues relevant to engineering network capabilities from different and often incompatible perspectives, e.g. global R&D/innovation strategies (Zander 1999; Von Zedtwitz, et al. 2004) or global product development practices

(Backhouse & Brookes 1996; Willaelt, et al. 1998; Subrahmanian, et al. 2005; Epinger & Chitkara 2006). These explosive developments within individual knowledge silos propose a risk to the consistent growth of this knowledge domain due to the lack of an overall framework.

This paper reports the key findings of our research designed to understand how to build network capabilities for global operations from an engineering perspective. A set of essential capabilities for global network operations were identified based on the existing literature and through deliberately selected case studies focusing on engineering activities. The case studies also demonstrated typical organisational features to support network operations with certain capability orientations. Evidenced by a series of forum meetings and pilot application projects, the output of this research can help managers to optimise their current engineering networks and design new engineering networks for the future success.

This paper is organised into five sections. The research approach will be introduced after this introduction with particular attention given to the research design, case selection criteria and methods of data collection and data analysis. Investigations into network capabilities and associated organisational features will be reported in section three and four. This paper concludes by a brief summary of the key findings and setting directions for the future research.

## **2. Research Approach**

This research adopted a theory building approach based on case study methods (Eisenhardt & Braebner 2007; Yin 2009). A reason for this research design is about the exploratory nature of this research because of the lack of existing theories or models based on which this research can develop hypotheses and test them. Another reason is about the complex and implicit nature of the research object. Network capabilities involve a vast number of interrelated factors and these factors are often embedded in the context of network operations. It's hard (if

possible) to understand the essential capabilities of an engineering network by other research methods, e.g. questionnaire based survey or experiments. An in-depth understanding of network capabilities perhaps can only be acquired through deep engagement with case companies and using complementary case study methods.

The cases were deliberately selected to include global network operations in different contextual situations. Main case selection criteria include (i) the cases should collectively present a cross-sector view, (ii) the scale of operations should be different and comparable, and (iii) the cases should demonstrate different business models reflected by the nature of products/markets, the concept of operations, or the general strategic orientations. Three core cases from the automotive sector, the electric and electronics sector, and the aerospace engineering sector will be reported in this paper.

In-depth understandings of network capabilities have been gained through longitudinal studies of the cases within the recent five years. Main data collection methods include documentary studies, interviews, and participant observations. Explored documents include company websites, second-hand cases, relevant literature, and company internal documents. Interviewees include engineering managers of group and division levels as well as frontline engineers. At least two interviewees were involved at each main business division. Most of them were interviewed multiple times in the beginning to explore key issues, later to develop the theoretical framework, and in the end to validate the findings. An interview lasted from 1 hour to 4 hours respectively. Peer academics and consultants advised the research and helped validate the key findings throughout the project.

A set of case study worksheets were developed to facilitate the process of data collection and data analysis in three main areas. The first area was to understand the contextual environment of the cases, including the industry sector, organisation structure, core business areas, main products, market dynamics and competitions, performance, etc. The second area was to

understand the essential network capabilities of the cases using a capacity maturity matrix which was based on the existing literature and further developed through the case studies (see Appendix 1). The third area was to understand the organisational features of the cases with a configuration approach (see Appendix 2). Guidance on how to build network capabilities for global operations were assessed based on the case studies and validated through forum meetings and pilot applications.

### **3. Essential Network Capabilities for Global Engineering Operations**

#### **3.1 Towards Engineering Network Capabilities and Theoretical Foundations**

Organisational capabilities have been considered as the ability of a team of resources to perform some tasks or activities (Grant 1991). Creating capabilities is not simply a matter of assembling a bundle of resources because capabilities involve complex patterns of coordination (or routines) between people and other resources (Grant 1991; Winter 2003). To gain capabilities from resources, an organisation needs to achieve integration, cooperation and coordination between individuals and teams (Grant 1991; Barney 1999; Mills & Platts, 2003). Capabilities leading to the sustainable competitive advantage of a company, also known as competences or core competences, are critical to businesses, will contribute value to customers, and are often embedded in different organisational functions of the company (Prahalad & Hamel 1990; Javidan 1998; Quinn 1999). Strategic resources contributing to such capabilities are believed to be valuable, rare, in-imitable and non-substitutable (Barney 1991). In changing environments, an organisation needs dynamic capabilities to create, integrate, and reconfigure resources into new sources of competitive advantages (Eisenhardt & Martin 2000; Helfat & Peteraf 2003; Teece, et al. 1997). Though the above studies talked about organisational capabilities in general, they provide a theoretical underpinning for understanding capabilities particularly for global network operations

Network capabilities to fulfil some specific functional requirements were addressed in the existing literature, especially in the areas of product development (Kusunnoki, et al. 1998), manufacturing (Shi & Gregory 1998) and supply chain management (Srai & Gregory 2008). Through integrating network capability elements in the existing literature and reflecting the nature of engineering operations, a preliminary conceptual model was developed to understand essential network capabilities for global engineering operations from four major perspectives. They are

- **Communication & sharing:** key issues addressed in the literature include resource accessibility (Singh, 2008), communication effectiveness (Brown & Eisenhardt, 1995), collaboration between internal and external partners (Van Echtelt, et al. 2008), social/informal networks (Allen, et al. 2007), knowledge sharing (Siemsen, et al. 2008) and best practice (Pearce, 1999).
- **Integration & synergising:** key issues addressed in the literature include common working approaches (Barczak & McDonough, 2003), collective problem solving styles (Willlaelt, et al. 1998), quality management (Foster 2008), product lifecycle management (Subrahmanian, et al. 2005), international operations synergies (Birkinshaw & Hagström, 2000), modularity and standardisation (Salvador, et al. 2002).
- **Innovation & learning:** key issues addressed in the literature include creativity and innovativeness ( Hoegl & Parboteeah 2007), cross-discipline learning (Tiwana & Bush, 2005), intellectual property (IP) protection (Thamhain 2007), continuous improvement (Anand, et al. 2009), key individuals (Moore & Birkinshaw, 1998), and customer intimacy (Lettl, et al. 2006).
- **Adaptation & restructuring:** key issues addressed in the literature include out-sourcing/off-shoring (PTC 2005), people-centric (Hong et al. 2008), core competency development (Santiago & Bifano 2005), flexible working approach (Mudambi, et al.

2007), risk management (Fraser, et al. 2003), remote design and 24-hour engineering (Eppinger & Chitkara 2006).

### **3.2 Case Studies to Refine and Enrich the Preliminary Capability Model**

Essential network capabilities for global engineering operations have been refined and enriched through a series of case studies. Details of case A, B and C will be introduced with an emphasis on their distinctive capabilities because they demonstrate typical combinations of the capability elements, and can collectively present an overview of essential network capabilities for global operations.

#### **3.2.1 Case A**

Case A is one of the world's largest producers of cars and trucks. The company manufactures and distributes automobiles in 200 markets globally. It generated revenues US\$174 billion in 2007 and had above 300k employees world-wide. The engineering network of case A consists of a research laboratory in the US aiming at basic research; three vehicle programme centres in the US, the UK and Germany, aiming at creating new vehicles from concepts to products; and many minor engineering centres supporting the vehicle programme centres or adapting vehicles to local markets. Table 1 presents an overview of case's global engineering network capabilities.

The global engineering network of company A has been evolving towards greater efficiency and integration since the beginning of the last century. There had been two drastic restructuring programmes by the 1970s which brought together isolated operations in separate countries to achieve economics of scale and scope through rationalisation and coordinated operations. Main reasons for the reorganisations were resource duplication and conflicting interests of different countries which resulted mainly from historical reasons and communication barriers. Since the 1990s, driven by increasing competition pressures, three world-wide initiatives have been launched to bring Europe and the Americas together for

integrated transatlantic operations, build up a platform for sharing and collaboration across brands and countries, and achieve greater benefits of economics of scale.

Table 1. Company A’s Global Engineering Network Capabilities

	Capabilities	Maturity	
<b>Communication and Sharing</b>	accessing dispersed technologies, expertise or talents	managed	<b>from managed to optimising</b>
	effective communication across locations, languages, cultures, time zones, and organisation boundaries	managed	
	cooperation between teams and brands along vehicle programs	managed	
	commoditised solutions for reuse and sharing, standardised components, solutions, or processes across the company	optimising	
	the global product development system integrating best practice of the brands	managed	
<b>Integration and Synergising</b>	common working approaches across the company; commonality models; optimising vehicle architecture	optimising	<b>from managed to optimising</b>
	collocated teams to develop leading solutions	managed	
	integrated concurrent engineering, collaborative engineering and product lifecycle management systems	managed	
	international operations synergies for economics of scale and expertise sharing	managed	
	quality focus in global operations and collaborations	managed	
<b>Innovation and Learning</b>	leaving room for creativity or innovation of brands and countries	repeatable	<b>from repeatable to managed</b>
	institutionalised learning	managed	
	identifying and developing core technology areas	repeatable	
	customer-focused car programmes	initial	
	continuous improvement	managed	
<b>Adaptation and Restructuring</b>	24 hours engineering	initial	<b>repeatable</b>
	managing main suppliers strategically, lean supply chain management	repeatable	
	flexible operating methodologies	initial	
	failure mode and effect analysis (FMEA) tools; reliability and compatibility check lists; world-wide engineering release system	managed	

Case A’s global engineering network seeks for greater efficiency, speed and quality through improved communication, knowledge reuse, and operations synergising. Dispersed engineering resources are brought together with cross-company standards and common working procedures, e.g. the worldwide engineering release system and the global product development system. The worldwide engineering release system reduces repetitive work in individual engineering centres. The global product development system allows new vehicles to be created with lower cost, higher speed, and better quality. By adopting the global product development approach, the number of engineering changes required for a new vehicle has been reduced more than 50% on average, and at the same time, the time to get an all-new vehicle to market has been reduced by 27%.

Commonality models and commodity business plans facilitate efficient co-operations between engineering centres on a global scale. Four levels of commonality have been adopted across the company: architectures, shared technologies, power packs, and commodities. Shared vehicle components and platforms have reduced the development costs of some vehicle programmes by as much as 60%. Cross-brand commodity plans have been adopted to reduce the number of variants and to maximise economies of scale.

Best practices, core technologies, and expertise are developed and used across the brands. A committee formed by high-level experts from all the brands takes the responsibility of identifying systems which should be designed as core, i.e. systems which are common or scalable across brands. To enable the integration and synergising of engineering operations on a global scale, customer-driven quality management has been implemented as a high priority task at all levels of engineering processes. Global quality operating systems and six-sigma tools/metrics are aggressively implemented across the company.

Case A has concentrated on further integrating its brands globally in the recent years. The company sold out its major operations in premier automotive markets in order to concentrate on mass market operations. Programmes have been set out to further exploit its global network capabilities in the Europe since 2002 and in the Americas since 2006.

### **3.2.2. Case B**

Case B is one of the world's leading suppliers of fast moving consumer goods (FMCG) with strong local roots in more than 100 countries. The company had about 174k employees and generated annual sales of €40.5 billion in 2008. The business of company B is managed with three regional teams and two category teams. The regional teams are primarily responsible for winning with customers and deploying brand events and innovations effectively. The category teams are fully responsible for brand development and innovation, as well as brand and

category management. Table 2 presents an overview of case’s global engineering network capabilities.

Table 2. Company B’s Global Engineering Network Capabilities

	Capabilities	Maturity	
<b>Communication and Sharing</b>	building centres of excellence for regional and global innovation	managed	<b>from managed to optimising</b>
	engineering portal for communication	managed	
	informal networks of engineers and managers	optimising	
	long term relationship with external partners, e.g. early equipment management	optimising	
	sharing across regions and categories, e.g. global engineering teams	managed	
	identifying and transferring best practices, e.g. technology platforms	managed	
<b>Integration and Synergising</b>	common working procedures	initial	<b>from initial to repeatable</b>
	synergising operations along regions or categories; rationalising brands; building success brands portfolio	managed	
	developing and maintaining standards across the company, e.g. global engineering teams and technology platforms	repeatable	
	integrated concurrent engineering, collaborative engineering	initial	
<b>Innovation and Learning</b>	learning across categories, brands, or regions; training; engineering academy; collaborative behaviour and culture	optimising	<b>from managed to optimising</b>
	leaving room for risk and diversity to foster innovation; being sensitive to difference, managing intellectual property (IP) systematically	managed	
	feeding key individuals (experts or specialists) into engineering academy	managed	
	understanding people to build brands, customer intimacy; winning with customer	optimising	
	total productivity management (TPM) or TPM like programmes	optimising	
<b>Adaptation and Restructuring</b>	out-sourcing support functions	repeatable	<b>from initial to repeatable</b>
	flexible working approaches	initial	
	working along the clock and the globe	initial	

Company B has engineering resources dispersed among two business categories and three geographic regions. These resources are deployed in three types of centres around the world focused on supporting brands health, development and innovation. Six principal research and development laboratories (two in the UK, one in Holland, one in the US, one in India and one in China) aim at long term technology development and work closely with categories to create or maintain excellent brands. Research and development centres in most countries operate closely with local markets for medium term innovations. Many product technology centres collocated with manufacturing sites support existing businesses. In addition, there is a corporate technology and engineering group to make sure that engineering goes the same way across the world by issuing standards/guidelines, providing advices, audits, and intensive training programmes.

Historically, company B had a central engineering team and later dispersed to different countries and operated autonomously. There were two drastic reorganisations in the 1960s and in the 1980s to increase the central control along product categories and functions in a view to gaining potential global efficiency. Currently, driven by the increasingly dynamic business environments and competition pressures, the company is experiencing a restructuring programme for sustainable success with local markets, as well as greater global efficiency through further integration, consolidation, and rationalisation.

Engineering operations contribute to the success and growth of case B's businesses by supporting new product development, commercialising new concepts, and improving customer services through delivering reliable and safe operations. The global engineering network of company B seeks for innovation and excellence through collaboration and sharing. Market-driven innovation guides the development of technologies, products and brands. Understanding people to build brands is considered as a basic principle for case B's engineering operations, which has been interpreted by its Chairman like this: "*[understanding people means to] meet the everyday needs of people everywhere, anticipating the aspirations of the consumers, and raising the quality of life*". This allows the company to develop innovative products and solutions for people, and at the same time to develop its people to grow the businesses. A series of methods and techniques have been developed for understanding customer needs, e.g. customer intimacy, gaining consumer insight, risk taking, encouraging diversity, and winning with customers (who are often large retailers).

Learning and sharing across regions and categories are facilitated by a set of tools, standards, processes and supportive corporate culture. An engineering portal has been established for engineering data management. Technology platforms have been formed to maintain standards and to ensure the implementation of best practice along key product lines. The engineering excellence team (EET) has been formed to bring the dispersed experts and specialists together

for standards development and collective problem solving. The global engineering team (GET) ensures that the EET is actually delivering what the regions need by directing the EET working program with proper strategies and structured working approaches. The engineering academy (EA) ensures the consistency of engineering knowledge, especially the intangible knowledge of key individuals, which is crucial to engineering problem-solving but very easy to lose when people move to different roles or leave the company. Cross-posting (or rotation) across subsidiaries, countries and categories has been used to establish unity, a common sense of purpose, and an understanding of different cultures and attitudes. The concept of virtual site (VS) aligns subsidiaries by technologies or geographic regions. Its CEO made the following comment on the importance of sharing and collaboration: *“clearly, not all of the creative ideas used to market skin cream are applicable to instant soups, but a surprising number of good ideas result from cross-fertilisation between product groups.”*

For further innovation and excellence, the company has launched the ongoing restructuring program focusing on four key areas: strategic priorities, capabilities, organisation structure, and culture and behaviour. A primary working plan has been developed around these four areas, including building a winning portfolio of businesses, developing core capabilities, building a fit-to-compete organisation, and encouraging collaborative culture and behaviour.

### **3.2.3 Case C**

Case C is the aerospace operations of a global engineering group. It is a global first tier supplier of airframe structures, components, assemblies and engineering services to aircraft prime contractors. It had over 6k employees, and generated revenues of US\$820 million in 2007. Table 3 presents an overview of case’s global engineering network capabilities.

Case C possesses expertise in a wide range of specialist aerospace manufacturing and design processes in addition to supply chain and logistics competencies. It has about 1,000 aerospace engineers distributed with customer bases, technology bases, and manufacturing facilities

throughout Europe, the Americas, Australasia and Asia. Countries with strong engineering capabilities include the US, Mexico, the UK, Germany, India and Australia. Case C has 21 centres of excellence around the world, and each of which possesses different types of global leading technologies or expertise. Case C also operates a semi-independent and fully-capable engineering arm which employs around 2000 aerospace engineers with access to 500 systems and software engineers.

**Table 3. Company C’s Global Engineering Network Capabilities**

	Capabilities	Maturity	
<b>Communication and Sharing</b>	21 centres of excellence to access globally dispersed technologies or expertise	managed	<b>managed</b>
	IT networks linking engineering centres and customer bases	optimising	
	informal networks of engineers /managers	managed	
	semi-independent engineering arm; joint engineering centres with customers	managed	
	technology committee or sub-committees to identify and transfer best practices	managed	
<b>Integration and Synergising</b>	common working procedures	initial	<b>repeatable</b>
	joint problem solving	repeatable	
	integration along product lifecycle	repeatable	
	international operations synergies	initial	
	knowledge based engineering (KBE) to improve the speed and quality of repetitive engineering work	managed	
	quality focus of product, process and system	managed	
<b>Innovation and Learning</b>	systematic intellectual property (IP) protection when external partners involved	repeatable	<b>repeatable</b>
	leaving room for creativity/diversity	repeatable	
	KBE to capture intangible engineering knowledge	managed	
	human centric and customer intimacy	managed	
	continuous improvement	initial	
<b>Adaptation and Restructuring</b>	strategic out-sourcing/off-shoring for detailed engineering work	managed	<b>from managed to optimising</b>
	working around the globe and the clock	managed	
	managing engineering resources without relocation	managed	
	flexible working approaches	optimising	
	rigorous risk management through modelling and simulation	managed	
	working with customers and focusing on people	optimising	

The global engineering network of case C grows mainly through two complementary approaches. One approach is to develop a wide range of global leading expertise and technologies along the product lifecycle through strategic acquisitions. Acquired engineering centres usually possess unique technologies or skills. They join case C’s engineering network as new centres of excellence after re-organising their resources on a global scale and connecting them into the company-wide information system. This well developed integration process usually began with identifying core competencies, dividing/relocating resources,

modularising solutions, and standardising processes, which would bring some degree of efficiency to the re-shaped engineering network. The acquired centres operate autonomously. The other centres can access their expertise through the central engineering portal.

The other growth approach is based on improving access to customers with joint engineering operations. Evolution in this direction aims to increase the responsiveness to local markets. In the future, the growth through acquisitions will continue but might be at a slower pace for optimising the network structure or upgrading competencies. At the same time, the engineering network will pay an increasing attention to integration and operational excellence due to increasing competition pressures.

Capability development of case C's global engineering network is driven by the uncertain nature of the aerospace industry, which is getting increasingly global, concentrated, interdependent and dynamic. In the recent years, only a small number of aircraft manufacturers dominate the global markets, and increasingly move towards systems integration. The number of new programmes is decreasing. The customers (e.g. airlines or armies) pay an increasing attention to the total value along the product lifecycle. Under such circumstance, case C has to improve the scope and quality of its competencies, the global presence, and the relations with prime contractors to ensure the success of every single bid.

A key mission of case C's global engineering operations is to develop and maintain strategic flexibilities for any changes and uncertainties. Case C has developed a range of flexible, adaptable and pro-active operating approaches which are believed to be able to meet even the most demanding customers' requirements, e.g. on-site working, package work, integrated solutions, design & build, strategic relationships, dedicated and collocated teams, joint teams, or partnerships. These approaches are customer oriented and can be used on an integrated or standalone basis. Supported by its powerful global data management systems and engineering tools, engineers can easily switch between projects even without physical relocation.

The 21 centres of excellence are strategically located around the world and can operate from different time zones in 24 hours over sites in Australia, Europe, India and the Americas. The Follow-the-Sun Engineering programme allows continuous engineering operations around the clock and the globe. In addition to schedule/working time reduction, this programme also contributes to enhancing international partnership, accessing global resources, and improving quality through frequent peer checking.

Rigorous risk management improves the performance of existing engineering systems and helps to predict the performance of potential future systems/upgrades through assisting the development of requirements or establishing expected and specified performance levels. Important risk reduction tools include safety/reliability management, failure modes and effects analysis (FMEA), maintainability management, qualification and certification systems.

Focusing on the intangible knowledge of engineers makes the engineering processes flexible and effective. In a new programme, particularly at the stage of developing conceptual solutions, multi-skilled engineers will work closely with customers, often at customer bases, to make sure that customer requirements are well understood and conceptual solutions are worked out in an effective way. Personal relations are the basis for collaborations and selection of partners in many cases.

To cope with rapidly changing markets and emerging technologies, case C has strategically concentrated on a set of core competencies and significantly use external partners for outsourcing engineering operations. Case C has an established and quality-approved second-tier supplier base to provide peak and specialist engineering support.

Integrating the above elements together, the engineering network of case C is believed to be able to best serve its customers and handle the most complex programmes on a very flexible basis.

### 3.3. Cross-case Analysis and Global Engineering Network Capabilities

The concept of capability maturity helps to capture essential network capability elements for global engineering operations in an accessible format, and thus allows the comparison of the capability profiles of the cases. Figure 1 presents the capability profiles of the three cases.

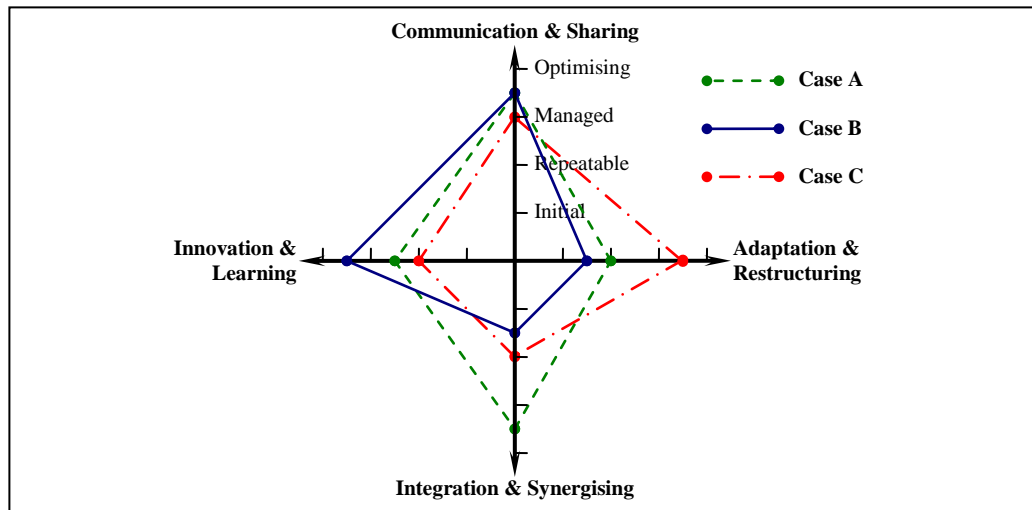


Figure 1. Global engineering network capability profiles

Essential network capability elements for global engineering operations were grouped into four main categories, which indicate different priority areas for global network operations.

- High priority areas for global network operations focusing on **communication & sharing** capabilities include assessing dispersed resources, effective communication across organisational, geographic and cultural barriers, knowledge sharing and re-use, and identifying and transferring best practice.
- High priority areas for global network operations focusing on **integration & synergising** capabilities include adopting common working procedures, joint problem solving, managing quality as top priority, integrating along product lifecycle, and synergising operations across countries, product lines, and business units (BUs).
- High priority areas for global network operations focusing on **innovation & learning** capabilities include encouraging creativity/diversity, understanding customers/leading core technologies, capturing the knowledge of key individuals and learning across

disciplines/BUs, managing intellectual property (IP), and searching for excellence and continuous improvement.

- High priority areas for global network operations focusing on **adaptation & restructuring** capabilities include adopting flexible working approaches and people centric, leveraging resources between projects/BUs, managing risks rigorously, strategic out-sourcing/off-shoring, and working around the clock and the globe.

#### **4. How to Build Network Capabilities for Global Engineering Operations?**

The previous section demonstrates how global leading companies compete with different network capabilities. We will continue the investigation to understand how to build the capabilities, i.e. how a global network is constructed to deliver the capabilities. Before start, we will need an overall framework to describe organisational features of a network in a systematic way.

##### **4.1 The Configuration Approach to Network Studies**

Network configuration concepts are well suited to studying complex, multivariate organisational phenomena (Mintzberg 1979; Miller 1986; Boyer, et al. 2000). With a configuration view, we are able to systematically describe organisational features of global engineering operations from five main perspectives (Zhang, et al. 2010), including

- **Network structure:** referring to the physical footprint of resources, including the size, number, types/roles of individual centres, and the rationale for network design.
- **Operations processes:** referring to the flow of material and information between members of the network to create valuable output to customers, e.g. new product development processes and lifecycle management processes.
- **Governance system:** referring to the mechanisms to direct and control the network, e.g. the authority structure, performance measurement and coordination mechanisms.

- **Support infrastructure:** referring to enablers for network members to collaborate with each other, e.g. information systems, tools, human resources, culture and behaviours.
- **Relationships:** referring to the interaction with external partners, e.g. suppliers, customers and users.

**4.2 Organisational Features of the Cases**

Figure 2 presents organisational features of the three cases from the five main configuration perspectives. Case A’s engineering resources are highly concentrated with three vehicle programme centres. Each programme centre has thousands of engineers and is fully responsible for a range of vehicles. There are also many minor centres dispersed with manufacturing facilities with responsibilities for supporting the vehicle programme centres or adapting vehicles for local markets. Engineering operations follow common processes based on the global product development system, and are centrally controlled with a set of metrics around financial health, quality, exciting products, competitive cost, revenue and market. Case A has developed an IT enabled platform for engineering operations across countries and functions, which is based on computer aided design, computer aided manufacturing, computer aided engineering and product information management. Case A’s engineering centres often work very closely suppliers to develop innovative cost reduction initiatives.

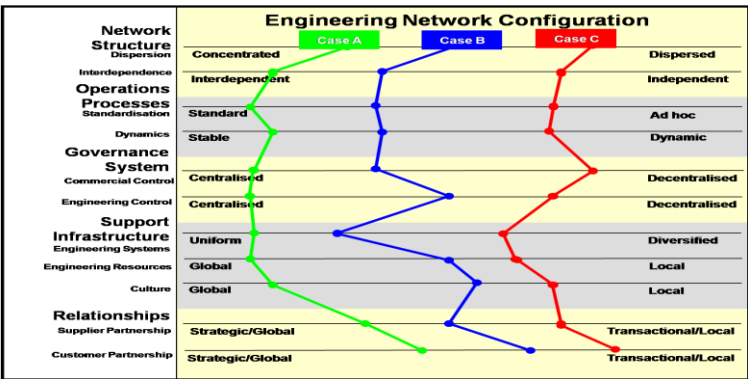


Figure 2. Organisational Features of the Cases

Case B’s global engineering network consists of six principle research centres with leading roles in some core technology areas and many R&D and product technology centres with

responsibilities for converting core technologies into innovative products. Case B has a central engineering group formed by experts and specialists from different business areas and countries to develop and maintain cross-company standards. The governance structure is made up of three primary dimensions: regions, categories and technology platforms. Different engineering tools are used in different countries and technology areas though an engineering portal has been established for central data management. IT services have been outsourced to a few contract partners including IBM and Accenture. Engineering teams work very closely with key customers and users to understand their needs and collaborate with external research organisations to access their global leading technologies or expertise.

Case C's global engineering network consists of 21 independent centres of excellence with different types of skills or expertise. There are also many engineering teams dispersed with customer bases. Operations processes are highly flexible and customer oriented. Engineering centres are responsible for local business development with the central corporate function reviewing their performance quarterly and the technology committee overseeing long term capability development. Case C has IT based engineering data management systems and programme management systems on a global scale, but different engineering tools are used in compliance with customers' engineering tools and systems. Case C's engineering centres develop very close partnership with main customers and maintain long term relationship with external engineering service providers to cope with fluctuations in demand.

#### **4.3 Guidance on How to Build Global Network Capabilities**

Observations from the case studies suggest some guidance for companies to build network capabilities with appropriate organisational features.

- Organisational features to support communication & sharing capabilities include network members with well-defined roles, common processes in key operations areas, centralised governance on strategic issues, company-wide information systems, and strategic management of extended supply networks.

- Organisational features to support integration & synergising capabilities include: concentrated resources focusing on capacity utilisation, standardised processes and commonality models, tight and centralised control, common supporting tools/systems, and lean supply chain management focusing on efficiency.
- Organisational features to support innovation & learning capabilities include: leading centres in core technology areas, adaptable processes allowing bottom-up idea generation, autonomous governance systems of regions or business groups, dedicated support tools/systems in core technology areas, and close relationship with main customers, suppliers and external research organisations.
- Organisational features to support adaptation & restructuring capabilities include: dispersed resources and independent centres of excellence, customised processes for local needs, decentralised control with central influence, tailored support tools for local needs, and agile supply chain management focusing on responsiveness.

The above findings have been validated by a series of forum meetings and pilot application projects. Two forum meetings have been organised focused on network collaborations and engineering performance respectively. The findings have also been tested through pilot application projects focusing on global engineering strategy development or global engineering network restructuring. Tools adapted from the case study worksheets were used to facilitate the meetings and workshops.

Feedback from the pilot applications suggests that the network capability and configuration models provide a systematic approach to analysing global network operations, and at the same time contribute to a common language which will help engineering managers with different functional roles to communicate with each other to achieve good consensus or identify common problems. The models will also help managers to demonstrate a high-level vision of their global networks while breaking the whole issue into manageable elements. In addition,

the pilot applications demonstrate the consistency of organisational features to deliver network capabilities, which will guide companies to optimise their global network operations or design new networks to better support their businesses or customers.

## **5. Conclusion**

This paper improves the understanding of network capabilities for global operations from an engineering perspective. Essential network capabilities were captured by in-depth studies of deliberately selected global networks focusing on engineering activities. Based on the existing literature and further developed through the case studies, a conceptual model was proposed to present network capabilities for global operations from four main perspectives: communication & sharing, integration & synergising, innovation & learning, and adaptation & restructuring. This model integrates key capability elements for global network operations with different functional requirements and has been refined and enriched by engineering cases. This contributes a step further towards a generic understanding of network capabilities for global operations.

The case studies also demonstrated some typical organisational features to support global network capabilities from five configuration perspectives: network structure, operations processes, governance system, support infrastructure, and relationships. These organisational features can guide companies to build appropriate network capabilities for their particular business needs, as validated by a series of forum meetings and pilot application projects. This research also suggests that companies should consistently align network capabilities with their business goals in changing environments because a company's global network that led to the past success might not be appropriate for the current situation.

Methodological and practical limitations of this research are closely related to its theory building nature. It is still too early to articulate any cross-sector archetypes as reference

models for network design and operations. More empirical studies within and across industry sectors are required to draw common conclusions that will be helpful for the design and operations of global networks in a particular situation, particularly the ones that might have significantly different demand for network operations, e.g. luxury goods, software, service operations, hi-tech and emerging industries.

This paper also suggests two main areas for the future research. Firstly, it would be particularly valuable to investigate how companies consistently align their network capabilities with changing contextual environments. Secondly, it would be of great value to investigate the unique capabilities and organisational features of collaborative networks formed by companies with different sizes.

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### **Reference**

- Allen, J., James, A. & Gamlen, P. 2007. Formal versus informal knowledge networks in R&D: a case study using social network analysis. *R & D Management*, 37(3), 179-196.
- Barczak, G. & McDonough, E. F. 2003. Leading Global Product Development Teams. *Research Technology Management*, November-December, 14-18.
- Barney, J. 1991. Firm Resources and Sustained Competitive Advantage *Journal of Management*, 17(1), 99-120.
- Barney, J. B. 1999. How a firm's capabilities affect boundary decisions. *Sloan Management Review*, 40, 137-145.
- Bartmess, A. & Cerny, K. 1993. Building competitive advantage through a global network of capabilities. *California Management Review*, 35, 78-103.
- Bartlett, C. A. & Ghoshal, S. 1988. Organising for Worldwide Effectiveness: The Transnational Solution. *California Management Review*, Fall, 54-74.
- Bernus, P., Nemes, L. & Schmidt, G. 2003. *Handbook on Enterprise Architecture*. Springer, New York.

- Birkinshaw, J. & Hagström, P. 2000. *The Flexible Firm: capability management in network organizations*. New York: Oxford University Press.
- Boyer, K.K., Bozarth, C. & McDermott, C. 2000. Configurations in operations: an emerging area of study. *Journal of Operations Management*, 18(6), 601-604.
- Brown, S. L. & Eisenhardt, K. M. 1995. Product Development: Past Research, Present Findings, and Future Directions. *Academy of Management Review*, 20(2): 343-378.
- Dicken, P. 2003. *Global Shift: Reshaping the global map in the 21<sup>st</sup> century*. London: Sage Publications.
- Dunning, J.H. 1993. *Multinational enterprise and the global economy*. Reading, MA: Addison-Wesley.
- Eisenhardt, K. M. & Martin, J. A. 2000. Dynamic Capabilities: What are They? *Strategic Management Journal*, 21, 1105-1121.
- Eisenhardt, K. M. & Graebner, M. E. 2007. Theory Building from Cases: Opportunities and Challenges. *Academy of Management Journal*, 50(1), 25-32.
- Eppinger, S. D. & Chitkara, A. R. 2006. The New Practice of Global Product Development. *Sloan Management Review*, 47(4): 22-30.
- Foster, S.T. 2008. Towards an understanding of supply chain quality management. *Journal of Operations Management*. 26(4), 461-467.
- Fraser, P., Farrukh, C. & Gregory, M. 2003. Managing product development collaborations- a process maturity approach. *Journal of Engineering Manufacture*, 217: 1499-1519.
- Grabher, G. & Powell, W.W. 2004. *Networks: Critical Studies in Economic Institutions*. Edward Elgar Publishing Limited, UK.
- Grant, R. M. 1991. The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation. *California Management Review*, 33(3), 114-135.
- Helfat, C. E. & Peteraf, M. A. 2003. The Dynamic Resource-based View: Capability Lifecycles. *Strategic Management Journal*, 24: 997-1010.
- Hoegl, M. & Parboteeah, K.P. 2007. Creativity in innovative projects: How teamwork matters. *Journal of Engineering and Technology Management*, 24(1-2), 148-166.
- Hong, P., Vonderembse, M.A., Doll, W.J. & Nahm, A.Y. 2008. Role change of design engineers in product development. *Journal of Operations Management*, (24(1), 63-79.
- Javidan, M. 1998. Core Competence: What does it mean in practice? *Long Range Planning*, 31 (1), 60-71.
- Koka, B. R., Madhavan, R. & Prescott, J. E. 2006. The evolution of inter-firm networks: Environmental effects on patterns of network change. *Academy of Management Review*, 31(3), 721-737.
- Kuemmerle, W. 1997. Building effective R&D Capabilities abroad. *Harvard Business Review*, March/April, 61-70.
- Kusunoki, K., Nonaka, I. & Nagata, A. 1998. Organizational Capabilities in Product Development of Japanese Firms: A Conceptual Framework and Empirical Findings. *ORGANIZATION SCIENCE*, 9(6), 699-718.
- Matos, L. & Afsarmanesh, H. 2004. *Collaborative Networked Organizations: A Research Agenda for Emerging Business Models*. NY: Springer.

- Leonard-Barton, D. A. 1992. Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development. *Strategic Management Journal*, 13, 111-125.
- Lettl, C., Herstatt, C. & Gemuenden, H. G. 2006. Users' contributions to radical innovation: evidence from four cases in the field of medical equipment technology. *R & D Management*, 36(3): 251-272.
- Mills, J. & Platts, K. 2003. Competence and resource architectures. *International Journal of Operations & Production Management*, 23(9), 977-994.
- Mintzberg, H. 1979. *The Structuring of Organisation*. Prentice Hall, Englewood Cliffs, NJ.
- Miller, D. 1986. Configurations of Strategy and Structure: Towards a Synthesis, *Strategic Management Journal*, 7, 233-249.
- Moore, K. & Birkinshaw, J. 1998. Managing knowledge in global service firms: centres of excellence. *Acad. Manage. Exec.*, 12: 81-92.
- Mudambi, R., Mudambi, S. & Navarra, P. 2007. Global innovation in MNCs: the effects of subsidiary self-determination and teamwork. *Journal of Product Innovation Management*, 34(5), 442-455.
- Pearce, R. D. 1999. Decentralised R&D and strategic competitiveness: Globalised approaches to generation and use of technology in multinational enterprise (MNEs). *Research Policy*, 28(2-3), 157-178.
- Perks, H.M. & Jeffrey, R. 2006. Global Network Configuration for Innovation: A Study of International Fibre Innovation, *R&D Management*, 36(1), 67-83.
- Podolny, J. & Page, K. 1998. Network forms of organisations. *Annual Review of Sociology*, 24, 57-76.
- Powell, W.W. 1990. Neither Market nor Hierarchy: Network Forms of Organisation. *Research in Organisational Behaviour*, 12, 295-336.
- PTC. 2005. *Gaining Competitive Advantage through Global Produce Development*. US: Parametric Technology Corporation (PTC).
- Prahalad, C.K. & Hamel, G. 1990. The core competence of the corporation. *Harvard Business Review*, May-June, 79-91.
- Salvador, F., Forza, C. & Rungtusanatham, M. 2002. Modularity, product variety, production volume, and component sourcing: theorizing beyond generic prescriptions. *Journal of Operations Management*, 20(5), 549-575
- Quinn, J.B. 1999. Strategic outsourcing: Leveraging knowledge capabilities. *Sloan Management Review*, 40(4), 9-21.
- Santiago, L. P. & Bifano, T. G. 2005. Management of R&D Project Under Uncertainty: A Multidimensional Approach to Managerial Flexibility. *IEEE Transactions on Engineering Management*, 52(2), 269-280.
- Shi, Y. & Gregory, M. 1998. International manufacturing networks: to develop global competitive capabilities. *Journal of Operations Management*, 16, 195-214.
- Sia, C.L., Teo, H.H., Tan, B.C.Y. & Wei, K.K. 2004. Effects of Environmental Uncertainty on Organisational Intention to Adopt Distributed Work Arrangements. *IEEE Transactions on Engineering Management*, 51(3), 253-267.

- Siemens, E., Roth, A.V. & Balasubramanian, S. 2008. How motivation, opportunity, and ability drive knowledge sharing: The constraining-factor model. *Journal of Operations Management*, 26(3), 426-445.
- Singh, J. 2008. Distributed R&D, cross-regional knowledge integration and quality of innovation output. *Research Policy*, 37(1), 77-96.
- Snow, C. C., Miles, R. E. & Coleman, H. J. 1992. Managing 21st Century Network Organisations. *Organisational Dynamics*, 20(3), 5-20.
- Srai, J., & Gregory M., 2008. A Supply Network Configuration Perspective on International Supply Chain Development, *International Journal of Operations Management*, 28(5), 386-411.
- Subrahmanian, E., Rachuri, S., Fenves, S., Foufou, S. & Sriram, R. 2005. Product lifecycle management support: a challenge in supporting product design and manufacturing in a networked economy. *International Journal of Product Lifecycle Management*, 1(1), 4-25.
- Teece, D. J., Pisano, G. & Shuen, A. 1997. Dynamic Capabilities and Strategic Management. *Strategic Management Journal*, 18(7), 509-533.
- Thamhain, H. J. 2003. Managing innovative R&D teams. *R&D Management*, 33(3): 569-588.
- Tiwana, A. & Bush, A. A. 2005. Continuance in Expertise-Sharing Networks: A Social Perspective. *IEEE Transactions on Engineering Management*, 52(1), 85-101.
- Van Echtelt, F., Wynstra, F., Van Weele, A. & Duysters, G. 2008. Managing supplier involvement in new product development: a multiple-case study. *Journal of Product Innovation Management*, 25(2), 180-201.
- Von Zedtwitz, M., Gassmann, O. & Boutellier, R. 2004. Organising global R&D: challenges and dilemmas. *Journal of International Management*, 10, 21-49.
- Willlaelt, S. S. A., De Graaf, R. & Minderhoud, S. 1998. Collaborative engineering: A case study of concurrent engineering in a wider context. *Journal of Engineering Technology Management*, 15, 87-109.
- Winter, S. G. 2003. Understanding dynamic capabilities. *Strategic Management Journal*, 24, 991-995.
- Yin, R. K. 2009. *Case Study Research: Design and Methods*. London: Sage Publications.
- Zander, I. 1999. How do you mean 'global'? An empirical investigation of innovation networks in the multinational corporation. *Research Policy*, 28, 195-213.
- Zhang, Y., Gregory, M. & Shi, Y. 2007. Global Engineering Networks (GEN): The Integrating Framework and Key Patterns. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 221, 1269-1283.
- Zhang, Y., Gregory, M. & Shi, Y. 2008. Global Engineering Networks (GEN): Drivers, Evolution, Configuration, Performance, and Key Patterns. *Journal of Manufacturing Technology Management*, 19(3), 299-314.
- Zhang, Y., Fleet, D., Shi, Y., Srai, J. & Gregory, M. 2010. Network Integration for International Mergers and Acquisitions". *European Journal of International Management*, 4(1-2), 56-78.

## Appendix 1: Global Engineering Capability Maturity Model

	Level I	Level II	Level III	Level IV
<b>Communication and Sharing</b> accessing and linking dispersed engineering resources	isolated resources	separating when projects complete	exchange resources regularly	interdependent engineering centres
<b>Integration and Synergising</b> coordinating engineering operations for global efficiency	standalone centres	initiatives of global project	regional or divisional coordination	international operations synergies
<b>Innovation and Learning</b> capturing and transferring internal and external knowledge	re-inventing the wheel	modularised solutions	institutional learning	innovation as a culture
<b>Adaptation and Restructuring</b> reconfiguring engineering resources for changes	arbitrary decisions of key individuals	established processes, but for reference	effective processes across the network	self-optimising

**Level I (Initial):** undisciplined and individualistic; there is no conscious process and a successful outcome may be accidental or dependent on the heroics of a few key individuals.

**Level II (Repeatable):** standardised; basic processes for communication and collaboration are established; standards exist, but are often sacrificed under pressure.

**Level III (Managed):** reliable and predictable; effective processes are consistently used across the company.

**Level IV (Optimising):** preventative, and self-optimising; processes are continuously improved and optimising.

## Appendix 2: Global Engineering Network Configuration Assessment

Configuration Elements	Metrics for Reference	Configuration Characteristics
<p><b>Network Structure</b> Physical 'footprint' of engineering resources, e.g.</p> <ul style="list-style-type: none"> <li>the size, number and types of engineering centres and their locations,</li> <li>interrelationship and resource sharing between centres</li> <li>the rationale for location decision</li> </ul> <p><b>Description:</b></p>	<p><b>Dispersion</b></p> <ol style="list-style-type: none"> <li>global engineering centres of corporate level</li> <li>global engineering centres of business unit level</li> <li>global &amp; regional centres</li> <li>regional centres for key products or technologies</li> <li>centres of excellence around the world</li> </ol> <p><b>Interdependency</b></p> <ol style="list-style-type: none"> <li>independent centres without resource sharing</li> <li>project based resource sharing occasionally</li> <li>regular cross-centre collaboration</li> <li>interdependent centres within product platforms</li> <li>interdependent centres across the company</li> </ol>	<p><b>For example:</b></p> <ul style="list-style-type: none"> <li>centralised assets or dispersed assets</li> <li>shared assets or independent assets</li> <li>global centres of excellence or local capability</li> <li>centres with different roles or centres without differentiation</li> <li>assets close to technology or manufacturing, customer, or user</li> </ul> <p><b>Comments:</b></p>
<p><b>Operations Processes</b> The flow of material and information between members of the network to create valuable output to customers, e.g. NPD&amp;I, lifecycle management, SC management, service and support, best practice identification &amp; transfer</p> <p><b>Description:</b></p>	<p><b>Standardisation</b></p> <ol style="list-style-type: none"> <li>no formal process, ad-hoc practices, mutually adjustment</li> <li>A process exists but just for reference on many occasions</li> <li>standardised process tailored for local or customer needs</li> <li>common process practiced around the world</li> <li>continuously improved common process</li> </ol>	<p><b>For example:</b></p> <ul style="list-style-type: none"> <li>defined standard common business processes (major) or ad-hoc local/customer tailing with only standards defined</li> <li>best practice globally defined or cooperative transfer by consensus</li> </ul> <p><b>Comments:</b></p>
<p><b>Governance System</b> Mechanisms to direct and control the network, e.g.</p> <ul style="list-style-type: none"> <li>authority structures</li> <li>monitor and control mechanisms</li> <li>performance measurement systems</li> </ul> <p><b>Description:</b></p>	<p><b>Centralisation of Commercial Control</b></p> <ol style="list-style-type: none"> <li>totally distributed control, local metrics</li> <li>distributed control with central staff having influential authority, BU and local metrics</li> <li>regional or business unit level control with global governance, BU metrics</li> <li>global governance through engineering committee, global KPIs &amp; BU metrics</li> <li>global governance through central engineering unit, common global KPIs</li> </ol> <p><b>Centralisation of Engineering Control</b></p> <ol style="list-style-type: none"> <li>totally distributed control, local metrics</li> <li>distributed control with central staff having influential authority, BU and local metrics</li> <li>regional or business unit level control with global governance, BU metrics</li> <li>global governance through engineering committee, global KPIs and BU metrics</li> <li>global governance through central engineering unit, common global KPI</li> </ol>	<p><b>For example:</b></p> <ul style="list-style-type: none"> <li>hierarchical strategic global governance, e.g. executive global VP or commercial (financial and contractual) central control only with delegated (operational) process freedom or totally distributed control with central staff having influential authority only</li> <li>common global KPIs or local flexibility</li> </ul> <p><b>Comments:</b></p>
<p><b>Support Infrastructure</b> Enablers for network members to collaborate with each other, e.g.</p> <ul style="list-style-type: none"> <li>Engineering tools,</li> <li>EDM, ERP, IT infrastructures</li> <li>Engineering resource management</li> </ul> <p><b>Description:</b></p>	<p><b>Unification of Engineering Tools</b></p> <ol style="list-style-type: none"> <li>isolated and customised engineering tools</li> <li>customised engineering tools linked by data exchange servers</li> <li>customised engineering tools for customers or technologies with compatible data format</li> <li>business unit level engineering tools linked with central EDM</li> <li>single engineering system across the company</li> </ol> <p><b>Unification of IT Support</b></p> <ol style="list-style-type: none"> <li>isolated and customised ERP &amp; IT support</li> <li>customised ERP linked by data exchange servers</li> <li>customised ERP for customers or technologies with compatible data format and process</li> <li>business unit level ERP systems linked with central data management systems</li> <li>single ERP systems across the company</li> </ol> <p><b>Globalisation of Engineering Resource Management</b></p> <ol style="list-style-type: none"> <li>local engineering resource management</li> <li>business unit level local engineering resource management</li> <li>business unit level local engineering resource management with global learning and transfer schemes</li> <li>business unit level local engineering resource management with global talent and capability management</li> <li>global local engineering resource management</li> </ol>	<p><b>For example:</b></p> <ul style="list-style-type: none"> <li>Unified single centrally defined and run IT system (CSC) or locally customised systems</li> <li>global talent and capability mapping and transfer management or local control and transfer by consensus</li> </ul> <p><b>Comments:</b></p>
<p><b>Relationships</b> Interaction with external partners, e.g.</p> <ul style="list-style-type: none"> <li>suppliers, customers or users</li> </ul> <p><b>Description:</b></p>	<p><b>Strategic Importance of Supplier Relationship</b></p> <ol style="list-style-type: none"> <li>do everything in house</li> <li>simple transactions &amp; arms length with suppliers</li> <li>keep core competencies in house and outsource non-core operations</li> <li>mutually beneficial partnership on key programmes</li> <li>long-term strategic relationship with partners on a global scale</li> </ol> <p><b>Strategic Importance of Customer Relationship</b></p> <ol style="list-style-type: none"> <li>contractual transactions with customers</li> <li>collaborative projects with customers</li> <li>partnership on key programmes regionally</li> <li>mutually beneficial partnership on key programmes globally</li> <li>long-term strategic relationship with customers on a global scale</li> </ol>	<p><b>For Example:</b></p> <ul style="list-style-type: none"> <li>global relationships with suppliers and deals mostly negotiated centrally (indirect suppliers) or supplier deals negotiated locally (direct suppliers)</li> <li>supplier treated as partners (strategic) with embedded staff or suppliers held at arms length (transactional)</li> <li>preference for in-house (make) or outsourcing (buy)</li> <li>customer relationships primarily global or primarily local (limited local relationship with users)</li> </ul> <p><b>Comments:</b></p>