Analyzing Social Capital to Improve Product Development Team Performance: Action-Research Investigations in the Aerospace Industry With TRW and GKN

Naomi J. Brookes, Sue C. Morton, Steve Grossman, Paul Joesbury, and Duncan Varnes

Abstract—Social capital is gaining preeminence as a concept to interpret the behavior of organizational entities, especially in new product development (NPD). Significant research is accumulating that links the performance of NPD teams with the patterns of social capital that they exhibit. The research suggests that analyzing teams' social capital could provide insights to improve substantively the performance of NPD teams. However, the pragmatic use of social capital presents a number of difficulties. Investigating and resolving these issues is vital if the concept of social capital can be used to achieve performance improvement. This paper reports on an investigation in the aerospace industry, the aim of which was to establish the feasibility of mapping and analyzing a team's social capital in order to provide insights and to highlight productive interventions. The investigation used an action-research methodology involving the codevelopment and coimplementation of solutions with two multinational companies, GKN Aerospace and TRW Aerospace Group, and a management consultancy organization, the Rossmore Group. This paper reports on the encapsulation of social capital research in a management tool and its application within GKN and TRW. The results of the investigation indicate that analyzing the social capital of NPD teams provides a useful approach to improving their performance.

Index Terms—New product development (NPD) teams, performance improvement, social capital, social networks.

I. INTRODUCTION

HE PREEMINENCE of the cross-functional team as the most effective organizational grouping for new product development (NPD), especially of complex products, is now widely accepted by the academic and practitioner communities alike. (For example, McDonough [1] highlights that companies now rely upon cross-functional teams for over 70% of their development effort.) The widespread implementation of cross-functional teams for product development is testament to the

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interplay of ideas between the academic and practitioner communities. In looking to enhance the performance of NPD teams further, a continued dialogue is vital.

One of the research disciplines that may yield new insights into NPD team behavior focuses around the concepts of social capital and social networks. NPD has long been regarded as not only a technical but also a social process, especially in complex product development. To illustrate, Eppinger and Salminen [2] have stated that:

The development of complex products and large systems is a highly interactive social process involving hundreds of people designing thousands of interrelated components and making millions of coupled decisions.

The importance of promoting social ties and relationships has already been reflected implicitly in the choice of the crossfunctional team as the preeminent form of organization for NPD. In addition, the concepts of social capital (including conceptions of "connectedness," networks, and relationship ties) are now being explicitly applied to NPD. A number of studies have established relationships between NPD performance and the social capital exhibited by the individuals and teams undertaking NPD [3]-[5]. What is now required is for the understanding derived from these studies to be embodied in a way that can be used by practitioners to improve holistically the performance of an NPD team, especially in terms of the team's relationships with key stakeholders during the NPD process. This paper reports on a coinvestigation between researchers and practitioners in two aerospace companies, GKN Aerospace Services and TRW Aerospace Group (ASG).¹

The paper begins by delineating the aims of the investigation and the methodologies employed. It presents the research context in the field of social networks, social capital, and NPD. It then reviews the context for the investigation in terms of NPD in the aerospace industry generally and in the specific cases of GKN Aerospace and TRW ASG. This paper describes the process of mapping and analyzing social networks and the ensuing process of using that analysis to change NPD team behavior within the subject organizations. This paper concludes by examining how far the results of the investigation support its original aim and what implications the investigation has for other

¹Since this research was undertaken, TRW ASG has ceased to exist as an organizational entity. Its component businesses have been sold to Goodrich.

practitioners with social network and social capital concepts to change the behavior of their NPD teams.

II. SOCIAL NETWORKS, SOCIAL CAPITAL, AND NPD: THE RESEARCH CONTEXT

The concepts of social networks and social capital are well established. Social networks have been used as constructs in social sciences since the 1950s (e.g., [6] and [7]). The features of the social network perspective have been summarized by Wasserman and Faust [8]. The social network perspective implies viewing systems in terms of relations between individual actors, where actors and actions are seen as interdependent rather than independent. The relational ties between actors allow the transfer of resources: physical- or information-based. Network structures are developed from combinations of these "dyadic" relationships between two actors. Network models explain structures in terms of lasting patterns of relations between actors. The mathematical analysis of networks, either in the form of sociomatrices or topologically, has formed the basis of a research perspective known as social network analysis (SNA) that has been documented exhaustively by Wasserman and Faust [8]. Seminal work in applying concepts of social networks to management issues was undertaken by Krackhardt and Hanson, with a summation of that experience presented in the Harvard Business Review [9].

Social capital has a 40-year-old provenance as a socioeconomic concept. In 1968, Cole [10] defined social capital as:

socially useful structures and institutions from railways to hospitals, possibly publishing houses and drug stores.

In the mid to late 1990s, researchers began to perceive social capital as a distinct resource for companies in the same way that "human capital" and financial capital can be considered [11]. Adler and Kwon [12] in their comprehensive review describe it as an "umbrella concept" in the "emerging excitement" phase of the life-cycle typical of a concept. Inkpen and Tsang [13] build upon this work to express social capital as:

The aggregate of resources embedded in, available through and derived from the network of relationships possessed by an individual or organization.

From this definition, the link between social capital and social networks is apparent. Increasingly, researchers have conceptualized social capital in terms of social network concepts [14]–[16]. Inkpen and Tsang [13] provide a very useful summation of current work in the area. Understanding the social capital possessed by a network will require de facto analysis and understanding of its social network.

Investigations into NPD are of a similar longevity to those in social capital and social networks. In the mid-1960s, Lawrence and Lorsch [17] proposed the now widely accepted theory of integration between functions to support successful innovation and NPD. Work continued on investigating NPD through the 1970s and 1980s [18]–[22]. Increasingly, competition in a global marketplace necessitated the strengthening of NPD capabili-

TABLE I
SUMMARY OF RESEARCH ON THE RELATIONSHIPS BETWEEN SOCIAL CAPITAL,
SOCIAL NETWORKS, AND NPD PERFORMANCE

Researcher	Key Propositions or Findings
Lee et al [48]	Demonstrated a link between R&D team's social capital and their innovative capabilities
McFayden et al [49]	Analyzed the relationship between individual social capital and knowledge creation to identify that the strength of relationships had a higher marginal effect on knowledge creation than the number of relationships
Reagans et al [50]	Teams should not be designed and managed by demographic criteria but by their members' social networks.
Fischer et al [51]	Identified the effects of management teams' social network on initial -public-offering success
Oh et al [52]	examines the role of informal socializing ties in the concept of 'group social capital' and group effectiveness
Yang et al [53]	sociogram analysis of best and worst performing teams. Cohesion was important but mattered less on advice networks
Hoegl et al [54]	Used a sample of 430 team leaders in software development projects to show that team perceptions alter individual's networks and performance
Ahuja et al [55]	Used virtual R&D groups to show that network centrality was a determinant of individual performance
Bresnen et al [56]	The importance of social processes, patterns and practices in project knowledge management
Huang et al [4]	Social capital plays a key role in shaping the level of coordination for knowledge integration in cross-functional projects
Cummings [57]	Heterogeneity of team networks important in promoting knowledge sharing
Athanassiou et al [58]	Identified the importance of a Top Management Team's social networks in determining the internationalization of a company
Mehra et al [59]	Used a sample of 116 member hi-tech firms to demonstrate that self-monitoring personalities and centrality in social networks were related to both individual and group performance
Mead [60]	Used social network analysis to model and analyze a project team structure
Reagans et al [61]	Examined the heterogeneity of R&D networks and related this to team productivity
Sparrowe et al [62]	Used a sample of 190 employees in 38 workgroups to show that social networks were related to individual and group performance
Hansen [63]	Weak network ties help with locating sources of information in NPD projects but strong ties are more important for transferring complex knowledge
Tidd [64]	Open organizational networks are more effective than closed for radical innovation

ties [23], [24]. NPD performance has been researched extensively and a wide range of concepts for improvement proposed [25]–[30]. A thorough review of empirical investigations into NPD especially in terms of process and organization is provided by Ernst [31].

The number of phases in NPD has been shown to vary from 6 to 13 (e.g., [32]–[38]). Extant research has concentrated variously on different stages of the product development process (c.f. [26], [32], [39], [40]) with the result that design team composition, extent of customer interaction, and communication between team members, for example, have been identified to have significant influence upon performance [21], [41], [42].

The NPD process is acknowledged to be of varying levels of complexity, frequently requiring the ability to obtain, interpret, and transform large amounts of information [43], increasingly from external to an individual's source of knowledge [44]. The frequency of interactions has been seen to increase where there are high levels of uncertainty [45]. Eppinger and Salminen [2] utilized a matrix-based methodology for assessing the patterns of interactions within, and for comparatively mapping interactions across the product development process. In complex NPD situations, however, direct comparison has proved difficult: "a perfect one-to-one mapping rarely exists in real and dynamic engineering design environments" [2].

NPD in the current climate of globalization, technological change, and strategic alliances is increasingly complex. Research into strategies that could be used to improve NPD performance by improving interactional relationships between teams, departments, organizations, and strategic alliances will be of major benefit. The potential for concepts of social capital and social networks to impact upon product development in this way, in particular global product development, has been recognized since the mid 1990s [46], [47]. The studies summarized in Table I have all supported the proposition that the social capital embedded in a network and the structure of a network could affect product development performance. These studies have either focused on NPD teams directly or have considered related issues of group performance or knowledge sharing required for effective NPD team performance.

It should be noted that the links between social capital, social networks, and NPD are not always identified as beneficial. Florida [65] highlights the potentially stifling effect of social capital in some situations. Hansen [63] shows that "weak ties" are better than "strong ties" between actors in gathering information and can lead to project tasks being performed more quickly.

The studies that have established a potential link between social capital and NPD team performance have largely been retrospective. Limited work has been performed in translating these results into methods of analyzing NPD teams, or any form of work group for that matter, that are informative and actionable for practitioners. These seem confined to Cross *et al.* [66] who used self-awareness of social networks to:

- promote effective collaborations within strategically important groups;
- 2) support critical junctures that cross boundaries;
- 3) ensure integration following restructuring.

The current investigation could, therefore, contribute to the research body by establishing the feasibility of providing practitioners with a way to use existing research to improve the performance of NPD teams.

III. INVESTIGATION AIMS AND METHODOLOGIES

The investigation was undertaken using an action-research methodology, which has its origins in the 1940s [67] and has been used for a wide variety of management research investigations (e.g., [68]–[72]). Action research is a "quasi-experimental" approach, whereby researchers make interventions in a client's "real-life" situation and use the results of the interventions to further their understanding. At the same time, the interventions made by the researchers also result in performance improvements that benefit the client. Its distinguishing features as a strategy for management research lie in the following.

Its duality of objectives for client and researcher—The action-research investigation always has two sets of objectives: those of the researcher (usually associated with testing and improving theoretical understanding) and those of the client (usually associated with improving performance in some way). Rapoport's [73] delineation of the aim of action research high-

Entry and Contracting

The development of mutually agreed goals, aims and objectives between the clients and researchers and the establishment of boundaries, provisos and controls in order to achieve successful client – researcher relationships



Diagnosis

A joint diagnosis of the extant situation by the researcher and the client to enable knowledge sharing and buy-in to arrive at an agreed sequence of actions.



Action

Implementation of the action sequence by the client with the assistance of the researcher



Evaluation & Withdrawal

The joint review of the results of the action sequence by the client and researcher to establish if the mutual aims of the investigation from the viewpoint of the client and researcher have been met. The withdrawal of the researcher from the situation.

Fig. 1. Stages of the action-research process.

lights the tight coupling of the needs of the researcher and the client:

Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework.

Its purposeful intervention in an extant situation—Gill and Johnson [74] emphasize that action research demands the direct intervention of the researcher in the situation. A direct intervention requires the encapsulation of research findings in some form of practitioner-focused tool. Action research is, therefore, uniquely placed in its potential for developing theory that will be of use to practice [75].

The stages involved in the action-research process are outlined in Fig. 1.

Design parameters for an action-research investigation have been summarized usefully by Huxham and Vangen [75], as follows.

- 1) *Overtness:* The degree to which the research aims of the investigation are revealed to the client.
- 2) *Visibility:* The degree to which the research process is visible to the client.
- Riskiness: The degree to which the research aims jeopardize those of the clients.

The aim of the researchers involved in the investigation reported in this paper was to establish the feasibility of mapping and analyzing the social capital of an NPD team in order to provide meaningful insights and to highlight productive interventions for that team. "Establishing feasibility" was comprised of two components.

- Establishing that it is actually feasible to holistically map social capital (as exemplified by social networks) for an NPD team—as Cross et al. [66] point out, "organizations are very different in their tolerance for disclosure of various types of social relations."
- 2) Establishing that a social network analysis can then prompt the provision of meaningful insights and highlight potential interventions that practitioners can use—rather than providing information that practitioners may find interesting in abstract but cannot actually implement.

The aims of the practitioners involved in the investigation were as follows

- For GKN Aerospace: To change the nature of the relationships between NPD teams and original equipment manufacturer (OEM) customers in order to support more strategic interactions.
- 2) For TRW ASG: To develop the inter- and intrateam relationships of a newly formed NPD team nested within larger program-based teams in the organization.

Action research demands the codevelopment and coimplementation of solutions. The researchers and practitioners formed a combined team to undertake the investigation. Known as the POINTER team, this team comprised the researchers from Loughborough University, representatives from the two aerospace companies involved in the NPD investigation (the Director of European Programs from GKN Aerospace and the Head of Program Sourcing from TRW ASG), and a representative from a management consulting company that specializes in formulating rapid and executable client solutions (the Operations Director—the Rossmore Group). The POINTER team identified jointly the target NPD teams in the practitioner companies, devised the tailored approaches to social network analysis used in the investigation, and project-managed the investigations within the practitioner companies. Blending practitioner and research expertise was very important in insuring that the aims of the action-research investigation were met. In Huxham and Vangen's terms [75], the investigation could be classified as "overt" and "visible." More specifically, the clients knew about the research aims of the investigation and the process of the investigation was clearly apparent. The investigation also carried a certain degree of risk for the participants in that, far from improving team performance, mapping social networks had the potential to exacerbate the effects of problematic relationships.

IV. THE PRACTITIONER CONTEXT

A. NPD in the Aerospace Industry

NPD in the aerospace industry is viewed as a fundamental business process for company survival and growth: levels of R&D in aerospace are consistently higher than those experienced in other industrial sectors [76], [77]. The criticality of the product development process is matched by its complexity both in terms of the piece-part count of new products and the leading-edge technology employed in them. Product development, therefore, tends to be a lengthy and risky process. The need to spread this risk has meant that product development

in the aerospace sector is collaborative and geographically dispersed [78]. For example, Airbus' new passenger plane, the A380, involves over 18,000 companies in more than 30 countries. The industry is also highly price-sensitive in both its civil and, increasingly, its military sectors with national allegiances superseded for lowest-cost options. This means that product development is subject increasingly to pressures to insure low cost of supply.

These macrolevel characteristics of aerospace NPD impact upon the characteristics of the NPD teams employed. Teams will need to be able to assimilate and incorporate a wide variety of information that resides with people outside of their work-unit. Information providers will not only be proximate to their own physical location but will exist across geographical and organizational boundaries. The team itself may be globally dispersed and need to surmount communication barriers. It will also need to exist in the complex hierarchy of teams that comprise the total product development activity for a new aerospace product. In this situation, developing relationships that enable a good flow of information is crucial to an aerospace NPD team's success. The role of social networks in developing these relationships may be invaluable.

B. NPD in GKN Aerospace

GKN Aerospace is the aerospace operation of GKN plc. It is a global independent first-tier supplier of structures, components, assemblies, and engineering services to aircraft and aero engine manufacturers. It possesses expertise in all specialist aerospace manufacturing and design processes in addition to supply chain and logistics capability. With this expertise, it offers total solutions to its customers making GKN Aerospace a preferred partner to the major airframe and power plant OEMs. It has 15 centers of manufacturing excellence in Europe, the Americas, and Australasia, with a total workforce that numbers over 5600 people.

GKN aerospace's strategic decision to move "upstream" to offer a complete solution capability to its customers has resulted in the continuing development of its engineering services arm. The integrated engineering capability of GKN Aerospace employs almost 1000 aerospace engineers throughout Europe, the Americas, and Australasia. Critical to the development of this capability is to provide NPD teams with the skills necessary to enable productive and effective cooperation and coordination with the project's OEMs and other engineering solution suppliers. GKN Aerospace perceived that their NPD teams needed to develop superior communication and relationship skills.

The action-research investigation focused on product development teams within GKN aerospace that were providing product development engineering services to several large airframe OEMs. These services focused mainly on the NPD within the OEMs' existing product ranges. GKN Aerospace wished to convert these business-to-business interactions from a tactical basis to one where the strategic responsibility for complete product solutions would lie with GKN Aerospace. Fig. 2 gives a schematic structure of these NPD activities.

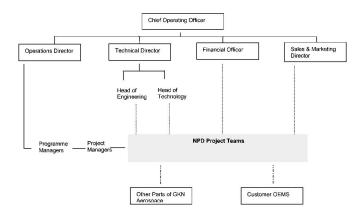


Fig. 2. Schematic organizational structure for GKN Aerospace Engineering Services.

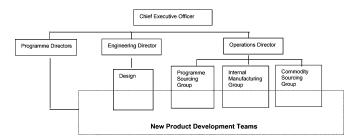


Fig. 3. Schematic organizational structure for TRW-ASG NPD activity.

The NPD teams were collocated within GKN Aerospace and comprised GKN staff. The team contained design engineers and program management personnel, but operated in a highly interdependent manner with the OEMs' engineering and project management functions. Improving NPD team and OEM relationships was viewed as crucial within GKN Aerospace. Part of the conversion of a tactical to a strategic relationship with the OEMs depended on improving these relationships. The action-research investigation was undertaken at the initiation of the Director of European Programs for GKN Aerospace. He anticipated that using a social network perspective to analyze the relationships between the NPD teams of GKN Aerospace and its OEMs would be useful in improving those relationships.

C. NPD in TRW ASG

TRW ASG was a first-tier OEM that was part of TRW, a multinational automotive company that had diversified into the aerospace business. TRW ASG was global in operation in terms of customer base and supply chain activity though most of the design activity still took place in the United Kingdom. TRW ASG had a turnover in 2003 of £1.2 billion. TRW ASG had recently undergone a significant strategic sourcing activity that had resulted in 30% of its components being resourced and making £25 million year-on-year savings. TRW ASG had also introduced a lightweight project structure to manage new product introduction (NPI) and had implemented its own NPI process that emphasized good project management practices and the concurrent development of design and manufacture. Fig. 3 gives a schematic structure of NPD activities in TRW ASG.

The investigation into social network analysis was undertaken at the initiation of the Head of Program Sourcing for TRW ASG. Part of the TRW ASG's procurement organization, the Head of Program Sourcing was responsible for a team of people known as the Program Sourcing Group (PSG). The PSG's role was to input knowledge of the supplier network to the product introduction process so that, at the end of the design stage, the supplier for the component would already have been identified and much of the necessary manufacturing documentation would have also been specified. The aim of the current investigation was to assist, not only in the reduction of product introduction lead times, but also product cost reduction by insuring leastcost manufacturing processes at a preselected supplier source. The function of the PSG was to act as an intermediary between the project-based NPI teams, the engineering function, and the operational procurement activity carried on elsewhere within the organization. In essence, it acted as an NPD team nested within larger program-based NPD teams.

The PSG was a new organizational grouping. It had been introduced in response to both the strategic sourcing and NPI initiatives that TRW ASG had recently implemented. This meant that members of the team were new to their role and, in a significant number of cases, new to the entire organization.

The Head of Program Sourcing identified that, as an NPD team, the PSG needed to:

- 1) interact more effectively with key stakeholders;
- 2) interact more effectively as a team to learn from and to support each other.

The Head of Program Sourcing was actively searching for a technique that would assist him in achieving these objectives and anticipated that a social network perspective may provide a solution.

V. TAILORING AN APPROACH TO MAPPING AND ANALYZING SOCIAL NETWORKS IN NPD TEAMS

A. The Need for a Tailored Approach to Analyzing Social Networks

The investigation needed to devise a tailored approach to mapping and analyzing NPD teams' social capital through the mapping and analysis of their social networks. Social network analysis is an extensive body of work and incorporates a wide range of many different (and, sometimes, complex) mathematical approaches. Not all of the network characteristics that can be identified by these analyses have been associated with aspects of NPD team behavior. Arguably, the existing research on social networks and NPD teams outlined in Table I has identified three key attributes of a network that will influence NPD team performance. These are:

- 1) centrality (a measure of the "connectedness" of individuals in the network);
- membership (who is and who is not a member of the network);
- 3) relationship strength (a quantitative measure of the nature of the relationships in the network).

Given the current state of researched knowledge, the tailored approach used in this investigation confined itself to

these network characteristics. (This is not to say that a future research project may find links between other social network characteristics and team behavior consistent with all other instances that would need to be incorporated at a later date).

In addition, the mapping and analysis techniques used in the investigation had to be readily comprehensible. NPD teams would need to understand quickly the approaches used and "buyinto" their results in order to generate meaningful insights and interventions. This limited the complexity and subtlety of analysis approaches. Mapping and analyzing techniques needed to be encapsulated in a format that was informative and actionable for practitioners.

The tailored approach to network mapping and analysis, therefore, needed to satisfy two criteria:

- to cover the aspect of networks that have been associated with NPD team behavior (i.e., centrality, membership, and relationship strength);
- 2) to be as simple and user-friendly as possible while remaining commensurate with 1), as shown earlier.

Tailoring an approach to mapping and analyzing also assisted in standardizing an approach. Each application of the mapping and analysis approach to an NPD team would need to triangulate with other applications. The process of triangulation would be assisted by applying the same approach to social network mapping and analysis in each case. A tailored approach to analysis would also provide an opportunity to standardize that would contribute to this objective.

B. A Tailored Approach to Mapping and Analyzing Social Networks

1) Operationalization and Collection of Data: "Strength" of network relationships was operationalized in terms of the success of that interaction in transferring the required information and resources. This is a different operationalization of strength than that adopted by other researchers in this field (e.g., [63] and [79]) who have tended to operationalize strength in terms of frequency of interaction and "closeness." This investigation's particular operationalization of relationship "strength" will not affect its internal logic, but may limit the ways in which it can contribute to the debate on the role of weak and strong ties in information and knowledge sharing.

Arguably, the measurement of interaction success embedded in the relationships made by participant team members could have been achieved using multi-item rather than single-item constructs (i.e., rather than asking a team member how successful interactions are with another individual, a series of related questions could have been asked and from this a single measure of trust formed from a conglomeration of responses). This is the logic of "domain sampling" [80] and the implications of this are that measures with more items are more reliable [81]. However, in pilot investigations, single-item and multi-item responses to rating correlated significantly, which gave the researchers confidence to only use single-item responses in the final approach to social network and analysis.

Team members were also asked to self-rate the interaction success of their relationships. Although self-ratings would not normally be utilized without some "objective" confirmatory rating, in this case it was necessary to rely on self-rating alone. Interaction success is a subjective concept necessarily rooted in the self-perception of the team member.

Collection of the data for network mapping was elicited via a *pro forma* document. The *pro forma* asked the participant NPD team member to name the individuals with whom he or she needed to interact for the NPD project. The *pro forma*, then, asked the individual:

- 1) to categorize these relationships by role (e.g., fellow team member, technical specialists, customer, program staff, etc.):
- 2) to rate these relationships on a scale of 1–4 (where 1 is *low*) in terms of how successful interactions were with that individual.

The *pro forma* documents were issued to the NPD teams by researchers at workshop events. NPD teams either completed them at this event or they were asked to return them by a given date to the research team.

- 2) Mapping the Network: All of the responses of the individual NPD team members were collated and used to create a social network map. The need to demonstrate the strength of relationships in the network meant that the chosen network representation needed to be, in social network terms, directional and relational. This type of information would usually be maintained in a sociomatrix (a matrix representation of a network), but, in order to remain easily usable, a graphical notation was selected. Fig. 4 demonstrates the network notation used. Network nodes represent individuals in the network and the lines show relationships between those individuals. The direction of the arrows indicates who has identified and rated the relationship (the arrow points in the direction of the individual identified), and the number on the line indicates the success of NPD-related interactions in that relationship. The shape of the nodes indicates the stakeholder group to which the individual belongs. For the purpose of clarity and to ease understanding, single relationships have been excluded. Only mutual relationships are shown throughout, i.e., individuals in the network who received two or more citations.
- 3) Social Network Analysis: Table II shows how the network characteristics identified as important to NPD team behavior were translated into units of analysis and how these, in turn, could be used to generate theoretical insights and interventions.

VI. MAPPING AND ANALYZING SOCIAL NETWORKS OF NPD TEAMS: THE ACTION-RESEARCH INVESTIGATIONS

A. Mapping and Analyzing in GKN Aerospace

1) The Investigation Process in GKN Aerospace: The data collection process was undertaken with the teams using a workshop format. Data was collected from each NPD team at separate team-focused workshops. The first part of the workshop was given over to trust-building and onboarding activities that aimed to make the NPD team participant comfortable in

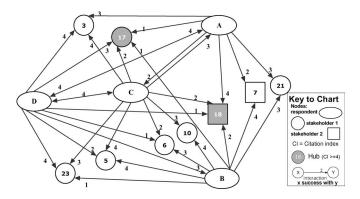


Fig. 4. Sample social network map.

TABLE II
TAILORED APPROACH TO SOCIAL NETWORK ANALYSIS

Network :haracteristic	Unit of Analysis for	Method of Calculation	Resulting Theoretical Insights
Centrality	Characteristic Number of 'Hubs'	A 'hub' is an individual that demonstrates 'nodal degree centrality' greater than 3 (i.e. an individual who has more than 3 identified relationships with other individuals)	or interventions If individuals who are hubs are situated outside the team, consider changing the formal organization position to make more accessible to team members (even to the extent of moving them into the team)
	Density of Intra-Team Relationships	The density of the network represents an aggregate of the networks centrality. (The denser the network the higher the average level of 'nodal degree centrality.') Data on reciprocal intra-team relationships can be collected (because all members of the team are polled) therefore density can be measured in terms of: n _i /n _i ,(n _n -1) (where n _r is the number of relationships between team members; n _n is the number of individuals (nodes) in the team.(c.f. Wasserman & Faust's density measure[18].)	If the network is sparse in terms of inter-team or relationships with other stakeholder categories, consider network building approaches If network is dense, then check that insularity and 'group think' is not a problem.
	Density of Inter Team relationships	Relationships outside the team cannot be reciprocal (because only team members are asked to identify relationships) therefore inter-team density needs to be measured in terms of: $n_0/$ n_n (where n_0 is the number of individuals (nodes) in the network not in the team; n_n is the number of individuals (nodes) in the team)	

sharing potentially sensitive network data. Network data was, then, obtained from the participants using the questionnaires that had been previously adapted to incorporate types of stakeholder contacts specifically tailored to GKN Aerospace. Network data was received from all workshop participants and, then, used by the researcher to create a social network. The resultant map was, then, presented to the NPD team participants. The researcher facilitated an analysis of the network and a discussion of this analysis to identify insights and interventions that could be derived from this analysis, which were recorded on flip-charts during the discussions. These records were, then, presented and "bought-into" by the teams' manager and the Director of Programs in the presence of the NPD teams and the researcher.

TABLE II (Continued)
TAILORED APPROACH TO SOCIAL NETWORK ANALYSIS

Relationship	Aggregate		If levels of
Strength	Aggregate levels of	n= k (Σ success _k)/ k	aggregate success
Strength	interaction	n=1	for inter-team
	success		interactions are low,
	between	(where success _k is the	consider ways to
	team	interaction success value for	increase trust
	members	each team member's	between team
		relationship with other	members (e.g.
		members of the team; k is the	barriers-to-
		number of relationships	communication
		between team members)	exercises)
	Aggregate	n= k	If levels of
	levels of	(Σ success _k)/ k	aggregate
	interaction	n=1	productivity are low
	success		between the team
	between the	(where success _k is the	and other
	team and	interaction success value for	stakeholder
	other	each team relationship with	categories, consider
	stakeholder	other non-team members ; k is	specific actions
	categories	the number of relationships	focused on building
		between team members and	trust between these
		non-team members)	groups
	Disparate	A disparate rating is one where	Consider sharing
	rating of	the highest and lowest	tactical information
	relationships	interaction success rating for a	about the
	with the	relationship with a specific	relationship between
	same	individual varies by 2 or more.	the team members
	individual by team		in question
	members		Consider directing all
	members		interactions through
			the team member
			with the more
			productive
			interaction
	Aggregate	n= n _r	Consider focused
	Levels of	Σ success/ n _r	training and
	Individual	n=1	development
	Interaction	(where success is the self-rated	programs for the
	Success	interaction success value for	particular individuals
		each relationship that an	or teams.
		individual has ; n _r is the	
		number of relationships that	
L		individual has)	
Network	Stakeholder		Consider if important
Membership	Groupings		stakeholder
	Present in		grouping are under-
	Network		represented in or
			missing from the
			network.
			Consider if the right level of role within
			stakeholder
			groupings are
			present in the
			network

2) The Results of the Investigation in GKN Aerospace: The social network maps for each of the NPD teams under investigation in GKN Aerospace are presented in Figs. 5–7.

The results of analyzing the networks are presented in Table III.

The following summarizes the insights and interventions on the basis of this analysis. The researchers found that a number of insights and interventions identified by NPD teams were a response to the investigation *per se*. (i.e., they would have been the same regardless of the social network map and its analysis.) The responses from NPD teams are, therefore, grouped into two categories:

- 1) insights that arose from the process of using social network mapping and analysis;
- 2) insights that arose directly from the results of the social network map and its analysis.

"Process" based insights and interventions.

The NPD teams reported that:

1) The process highlighted to them the importance of networking in ensuring success in their NPD activities.

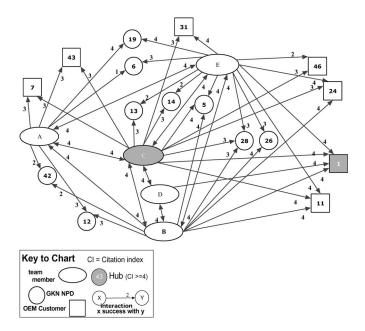


Fig. 5. Social network map for Team A.

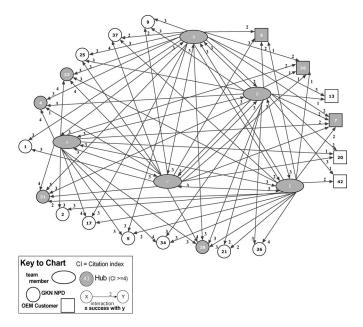


Fig. 6. Social network map for Team B.

- They became aware of the need to develop skills in improving the ways that they developed and maintained relationships.
- 3) The process made them think more carefully about who they should be creating relationships with, especially in terms of which NPD stakeholder groupings and the level of contact within those groupings.
- 4) The process produced a graphical expression of their relationships, which was very useful in assisting them in understanding the viewpoints of other team members. Team "C" specifically identified that they would like to use the map to bring "on-board" new team members.

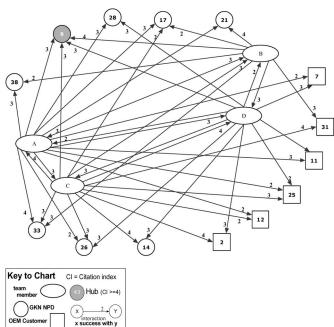


Fig. 7. Social network map for Team C.

TABLE III
SOCIAL NETWORK ANALYSES FOR NPD TEAMS IN GKN AEROSPACE

Network Characteristic for Analysis (GKN Aerospace)	Team A	Team B	Team C
Total number of relationships identified	80	102	68
Number of nodes internal to the team	5	5	4
Number of nodes external to the team	47	42	22
Number of Single citations (not shown in the network map)		17	17
Number of hubs		12	1
Ratio of Inter-Team Nodes/ NPD Team Nodes (Density)	4.2	5	4.5
Density of Intra-Team Relationships (Wasserman and Faust)		1.0	0.8
Aggregate level of interaction success between team members		3.0	3.0
Aggregate level of interaction success between the team and customer \ensuremath{OEM}		1.9	3.0
Number of Disparate rating of relationships with the same individual by team members $% \left(1\right) =\left(1\right) \left($		6	2
Percentage of NPD team members whose aggregate rating of interaction success in their relationship is <3.0	0	80%	25%

Results-based insights and interventions.

- Measures of centrality: No team used concepts of centrality (i.e., "hub" identification inter and intrateam density) to generate insights into the team's behavior or interventions in that behavior. (Teams A and C exhibited similar levels of centrality. Team B exhibited the greatest degree of centralized behavior.)
- 2) Aggregate levels of relationship connectivity with stake-holder groupings: All teams exhibited similar levels of aggregate intrateam interaction success and did not use this aspect in constructing insights and interventions. The comparatively low level of aggregate interaction success that Team B experienced with its OEM customer stake-holder grouping was important. Team B thought that this low level of aggregate interaction success was a very

- important factor in determining the level of success of their project. Team B did find it difficult to articulate why this situation had occurred as they perceived that they had significantly more successful interactions with the same stakeholder grouping on other projects.
- 3) Disparate individual ratings: Teams A and C used this dimension of the analysis to generate insights and interventions. Team A identified that some disparities were "latecomer" related, i.e., team members who had joined after the start of the project had less successful relationships than longer serving team members. Team A also sought third-party "conduits" who were members of their network outside the team to act as intermediaries with people with whom individual team members were having difficult relationships. Team C used disparities to identify which of the team members had better relationships with an individual outside the team and used the team member with the better relationships to act as a conduit for all of the team's interactions with this person. Team C also identified ways of "by-passing" difficult relationships while still gaining access to the required information and resources.
- 4) *Individual interaction success ratings:* Individual aggregate scores for interaction success were important to Team B in identifying issues with the team leader.
- 5) Network gaps: Team C identified that the right level of decision-making ability was not reflected in their current OEM customer contacts and, therefore, identified with whom they needed to develop relationships.
- 3) Evaluating the Investigation in GKN Aerospace: A measure of the efficacy of the insights and interventions generated by the application of social network mapping and analysis in GKN Aerospace was obtained by interviewing the Director of Programs (European Engineering Programs) at GKN Aerospace and by interviewing a sample of OEM customer representatives. The Director of Programs expressed his response in terms of the strategic capability of using social network analysis on the suite of NPD teams in GKN Aerospace in terms of building new types of relationships with customer OEMs:

(the investigation) it helped us implement our business strategy ... If I look back, we didn't have the relationship with the customer to do that, so what we've been able to do is to pick some of the small, elemental projects that we have within the business, use those as a platform to test out the tools that we've developed with (the researchers), and from that, significantly develop the relationship and build it into a level of work where we're doing more conceptual engineering work for (the customer OEM), ... We've now developed that further and, as I said, we are developing the process, the product and putting together a factory to build a (significant component for the OEM), and I think that the things we've done (with the researchers) have been fundamental to us enacting that strategy and that route forward. (Director of Programs)

Representatives of customer OEMs were asked how they thought relationships with the NPD teams in question had improved over the past 6 months and how they would rate the strength of those relationships (on a scale of 1–4) in terms of the levels of interaction success and trust in those relationships. The overall picture that these interviews presented was of growing and high levels of satisfaction with their relationships with the NPD teams who had applied social network analysis.

for [named team members], with trust it's four because I know they work hard to get the job done, and success is four too—it's the attention towards the task given to them. (OEM customer representative #1)

trust levels are pretty high—3 to 4, 3.5 for key members. And quite successful really, again 3.5—definitely grown. (OEM customer representative #3)

I trust them to work to the best of their ability—say 3, 4 on everyone of them.

measuring success [in relation to the outcomes of the relationship], against their targets, I'd rate them probably more than 3. (OEM customer representative #4)

Customer OEMs also indicate that the improved success may be due to having a stronger and better-defined team:

the team is very well defined and we have continuity with it. What I mean is that we deal with the same people... relationships helps get things done. (OEM customer representative #2)

B. Investigations in TRW ASG

- 1) The Investigation Process in TRW ASG: The process began with an "on-boarding" workshop with the researcher and the NPD team. The aims of this workshop were fourfold.
 - 1) To explain the investigation to the group in term of its activities and possible outcomes.
 - 2) To emphasize the "research" nature of the investigation and that the investigation is not a piece of consultancy.
 - 3) To explain the data-collection instruments to be used and how these should be completed by the team.
 - 4) To assure the team of the complete confidentiality to the researcher of their individual responses.

At the workshop, a questionnaire to be completed by the NPD team to create a social network for the members was distributed to the Group. The Group completed these questionnaires "offline" from the workshop over the next four weeks and returned the completed questionnaires to the researcher. A 100% response rate for questionnaires was received.

On completion of the questionnaires, a list of actors identified by all of the questionnaires was compiled. The researcher took this list and categorized these actors into stakeholder groups and placed them on an organizational structure chart for the company. The researcher used this data to create a social network mapping for the NPD team. This network map was presented to the NPD team as a whole at a workshop event specifically held for this purpose. The researcher then facilitated an analysis

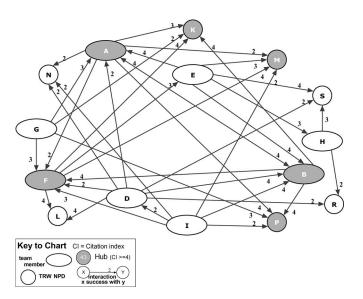


Fig. 8. Social network map for Team D.

of the network with the whole team, followed by a discussion to identify interventions on the basis of the analysis that could improve their performance and the performance of the team as a whole. The researcher was responsible for recording these insights and interventions. In addition, the team embarked on an immediate intervention to improve the network between them by undertaking an exercise to investigate the contributors and barriers to successful relationships between team members.

C. Results of the Investigation in TRW ASG

Fig. 8 is the social network map produced from the data supplied by the TRW ASG NPD team.

The results of analyzing the networks are presented in Table IV

The following summarizes the intervention and insights generated by the NPD team and recorded by the researcher.

- 1) Measures of centrality: Team D did not use the concept of hubs or interteam density to generate any insights or interventions. They did use the concept of intrateam density that clearly demonstrated the undeveloped nature of the relationships between them. This finding did not surprise them, but it did motivate them to work on intrateam relationship building. This factor (and the disparity in success in interteam interactions identified later) prompted them to embark on immediate trust-building exercises within the team.
- 2) Aggregate levels of interaction success between stakeholders: Team D did not use this aspect of the analysis to generate any insights, although they did note that the level of success they realized in intrateam interactions appeared slightly higher than that for interactions outside the team.
- Disparate individual ratings: As with Teams A and C, Team D used this information to generate a number of insights. Interteam disparities were identified as "new-

TABLE IV SOCIAL NETWORK ANALYSIS FOR THE NPD TEAM IN TRW ASG

Network Characteristic for Analysis (TRW ASG)	Team D
Total number of relationships identified	57
Number of nodes internal to the team	8
Number of nodes external to the team	7
Number of Single citations (not shown in the network map)	19
Number of hubs	6
Ratio of Inter-Team Nodes/ NPD Team Nodes (Density)	1.9
Density of Intra-Team Relationships (Wasserman and Faust)	0.4
Aggregate level of interaction success between team members	3.1
Aggregate levels of relationship success between the team and other stakeholder group $% \left\{ 1,2,\ldots ,n\right\}$	2.9
Number of Disparate rating of relationships with the same individual by team members	6
Percentage of NPD team members whose aggregate rating of interaction success in their relationship is <3.0	63%

comer" related: those individuals showing the less successful interactions were not only new to the NPD team but were also new to the organization. In order to improve disparate relationships outside the team, Team D shared information on relationships with individuals. This information ranged from program-related (e.g., "do not approach this person in the last week of the month as they are really tied up with project reporting") to the highly personal. (e.g., which football team an individual supported)

- 4) Individual interaction success ratings: Low levels of success were again associated with individuals who were new to the organization. As a result of this exercise, the Head of Program Sourcing used social networks as a tool for developing NPD team members, i.e., to act as a map of which relationships the NPD team member needed to improve and which relationships needed to be built from scratch.
- 5) Network gaps: Team D identified outright gaps in their network in terms of their direct dealings with suppliers and also identified that they needed to incorporate a different level of contact with individuals in program functions.
- 1) Evaluating the Investigation in TRW ASG: A measure of the efficacy of the insights and interventions identified by the investigation was provided by a questionnaire supplied to the NPD team participants and by interviewing the Head of Program Sourcing. The NPD team participants were asked to rate how comfortable they had felt in participating in the process and how comfortable they thought that other people would feel. The results from this exercise are shown in Fig. 9.

The NPD team participants were also asked what insights had been yielded by the process of mapping and analyzing their social networks. Sample responses to this question are provided in Table V. (Approximately 60% of respondents answered this question: There were no negative responses.)

The Head of Program Sourcing perceived that the use of social network analysis had provided him with an invaluable mechanism for developing the NPD team and improving its performance.

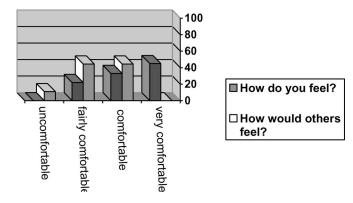


Fig. 9. Percentage distribution for perceived comfort in completing the questionnaire.

TABLE V SAMPLE RESPONSES OF TRW ASG NPD TEAM PARTICIPANTS

Sample Responses of PSG Members to the question "What insights has this process of this investigation given you?"

"The investigation has shown me that I don't easily form strong relationships"

"My job is to provide a service but I need to make all the effort to approach other people first"

"It has allowed me to think about how I perceive people and to think about who is key for me to be able to target to meet my objectives"

"My core network is actually quite small even though contacts on the peripherary are too numerous to list"

"Yes - my pattern of work contacts and how I split them into close relationships (based on personality) and work relationships (based on the job)"

"This mode of working requires me to go out and communicate - driving the network rather than being a hub"

I had inherited a fairly diverse team of managers and their job was to manage the supply chain for all new product introduction and, I have to say, it was, er, an interesting challenge because this was a group of individuals that did not operate as a team, that did not have any formal or working networking between themselves ... What we clearly identified (... from the investigation . . .) were a number of fairly significant failings in their operation, in that some of the key relationships that they should have been nurturing and pursuing and working very hard on didn't actually exist. So, one of the great outputs of the activity was to identify where I could realign their personal objectives and say, let's target some key individuals, and let's proactively build relationships with these people so that actually they can start adding value to the business. And I have to say that that was incredibly successful, not only in terms of their personal effectiveness, but also in terms of the effect it had on the team as a whole. I think we exited the process with a very coherent, coordinated and motivated team and I do put a very large influence on that to (this investigation). (Head of Program Sourcing-TRW ASG)

VII. CONCLUSIONS AND FURTHER RESEARCH

A. Support for the Aims of This Investigation

The practitioners considered that their aims for these investigations had been completely fulfilled. The Director of Programs at GKN Aerospace stated that the investigation had allowed him to identify and develop relationships with customer airframe OEMs: the Head of Program Sourcing at TRW ASG had considered this investigation vital in enabling him to develop a successfully functioning NPD team.

The research aims for this investigation were twofold.

- Establishing that it is actually feasible to map social networks for an NPD team.
- 2) Establishing that a social network analysis can, then, be used to provide meaningful insights and highlight potential interventions.

In the context of this investigation, it can be argued that these research aims were achieved. Social networks were mapped for four different NPD teams in two different organizations. The teams were willing to provide data that not only indicated the topology of their social networks but also rated the interaction success of the relationships within those networks. The feasibility of mapping social networks, especially with respect to the "organizational tolerance" for this sort of activity (c.f., Cross *et al.* [66]), has been demonstrated.

The ability of social network analysis to provide meaningful insights and highlight potential interventions has also been demonstrated in the context of this investigation. All of the participating NPD teams were able to use the analysis of their social networks to generate ideas and actions that their managers (and, in the case of GKN Aerospace, their customers) perceived to improve their relationships and, thence, their performance.

B. Extendibility of the Findings of This Investigation

One of the drawbacks of this type of action-research investigation is the limited nature of the population validity of its conclusions. The triangulation of the investigation findings across two organizations does go some way to extending its population validity. However, the organizations investigated were similar in terms of the size, structure, and composition of the participant NPD teams and in terms of the type of product that they were developing. Furthermore, the subject NPD teams in both organizations were newly formed within the structure of the existing organizations and, therefore, needed to cultivate different relationships with stakeholders. This may have meant that a social network approach to improve NPD team performance was of particular utility to them. Reasoning that the experience of this investigation would be replicated in the wider population is, therefore, dangerous. A number of features of the investigation may have influenced its outcome. These features may not necessarily be present if the investigation were to be undertaken in other company contexts:

1) Practitioner Involvement: The involvement with practitioners from TRW ASG, GKN Aerospace, and the Rossmore Group in every stage of the investigation and the codevelopment of the techniques used in the investigation may have contributed

greatly in increasing the "organizational tolerance" for a "social network" approach to improving NPD team performance. The "usability" of social network techniques utilized by the investigation was enhanced by being able to "pilot" them with practitioners prior to their implementation. The visible commitment of senior managers to the investigations was also very useful in getting NPD teams in TRW ASG and GKN Aerospace to participate fully in the investigations.

2) The Previous Experience of the Researchers: The researchers involved in this investigation had considerable experience in both the aerospace industry and in group facilitation. This enabled them to grasp the processes and terminology used in discussions with the team more quickly than someone who did not have this background. Additionally, the researchers possessed skills in group facilitation that enabled them to elicit contributions during team discussions.

On the other hand, the types of NPD in the organizations under consideration in this investigation are similar to a significant number of other companies within the aerospace sector. (There are over 3400 Aerospace companies with over 1000 employees in the United Kingdom alone.) They are also similar to other sectors embarking upon complex and risky NPD. The commonality of NPD team skill sets required by analogous companies would indicate that the use of social networks to improve NPD team relationships and performance may be feasible for any type of complex NPD.

C. Contributions to Existing Research

One of the issues that has received considerable attention in the field of social networks and NPD is the relative effectiveness of "strong" and "weak" network ties in knowledge transfer. Levin and Cross [82] provide a useful summary of the debate in the role of weak and strong ties. They review the discussions surrounding the role of weak ties and strong ties in the search and transfer of information and suggest that some of the apparent incongruities in research findings can be taken into account by considering other relational aspects of the ties such as trust and also by considering the nature of the information being transferred (e.g., tacit versus explicit). Hansen has highlighted the need to consider the complexity of the knowledge being transferred [63]. He has sought to further this understanding by arguing that knowledge transmission actually involves distinct phases (i.e., the decision to seek knowledge, seeking knowledge, and transferring knowledge). He also argues that different social networks with different characteristics are involved in each of the phases [83].

By operationalizing strength in terms of success of relationship interaction (i.e., not in terms of "closeness" or frequency of contact), this project makes a tangential contribution to the "weak ties" versus "strong ties" debate in knowledge sharing in NPD activities. In some ways, this project has bypassed these discussions. The tool has mapped the perceived success of dyadic relationships in transferring resource. (This project's operationalization of "strength" is strongly related to Levin and Cross's [82] operationalization of their outcome variable, "usefulness.") Whether this information has been transferred via

"weak" or "strong" links using more conventional understandings of these terms has, for reasons of pragmatic utility, not been considered. The nature of the resource transferred (in terms of its tacit or explicit nature or its complexity) has not been considered either. Additionally, Hansen et al.'s [83] phases of knowledge exchange do not map directly on to the project experience. The decision of the teams to seek information was a fait accompli. Teams had to communicate with external stakeholders (be they internal or external to the team) as these stakeholders had information or resources that were critical to the NPD task and unavailable to the team in any other way. The tool also operated on the implicit assumption that the dyadic characteristics of the relationships required to identify a source of knowledge were very similar to those required to effectively transfer it. (For example, it was assumed that it would be highly unlikely for one actor to admit to having the necessary knowledge if they were not willing to transmit it to the recipient actor.)

This project has shown that it has not been explicitly necessary for practitioners to understand the nature of relationships in a social network in terms of their "strength" in order to make changes to those networks where practitioners perceive the need to improve relationships. When the case-study teams were in the "analysis" phase of using the tool to identify interventions, they did not seek to improve the "information carrying" ability of relationships through improving the relationship's strength. (No recommendations addressed making dyadic relationships stronger through increasing the frequency of the interactions or through recommending that the actors become "closer.") Their interventions focused on the network topology. They sought to access the same information through more successful relationship "routes" in the network or to identify where new relationships needed to be made. This may indicate a strong topographical aspect to the success of knowledge transfer in social networks, which may provide a fruitful addition to the current focus on relational aspects of dyadic network ties.

The experiences of this project could also contribute to the debate surrounding the effect of social network "type" on successful knowledge transfer within that network. Inkpen and Tsang [13] highlight three network archetypes that have been used in investigating social capital and knowledge transfer. They characterize these archetypes as:

- intracorporate networks—which exist within a unified corporate identity;
- 2) strategic alliances—groups of firms entering into voluntary arrangements;
- 3) industrial districts—groups of firms operating in the same market segment within a shared geographic locality.

They propose that caution should be exercised in transferring learning about networks from one network type to the other, and in identifying the boundary conditions between network types. The NPD teams mapped in this project, especially in terms of GKN Aerospace, demonstrate a "hybrid" network type with some elements of intracorporate and strategic alliance characteristics. The work of this project highlights the need to extend Inkpen and Tsang's call for further research in boundary conditions into further research of network archetypes and their characteristics.

There is a longstanding stream of research that looks at "boundary bridging" roles for transmitting information in innovative activities such as NPD. A pertinent role-type that relates to this investigation is that of the "gatekeeper". Tushman [84] identifies the gatekeeper as a key node that links an external to an internal network. The role of a gatekeeper is not only associated with increased power [85] but also with the potential for role misalignment [86]. The issue of boundary spanning remains of current interest [87]. The case-study teams in this investigation (particularly those based in GKN) did demonstrate a manifestation of the gatekeeper phenomenon. Individual team members could be identified who had substantively higher numbers of dyadic ties with external stakeholders. In analyzing interventions to the network, "gatekeepers" did offer to "share" their relationships (i.e., facilitate other team actors in establishing their own dyadic relationship with the stakeholder.) This provides an interesting example of gatekeepers being willing to "diminish" their personal power. No evidence emerged in the case-studies for the inimical effects of the disappearance of a single point of contact between a team and a stakeholder though these could be envisaged. This may arise if:

- too much information was transmitted through relationships, which, then, led to decision making becoming more time-consuming due to consideration of this increased information;
- erroneous information that was not subject to formal routes of validation was transmitted through relationships.

Current research suggests that this may not practically be problematic, certainly in the cases of radical innovation [88], [89], though there is some debate in this arena (e.g., Florida [65]) and this does highlight that more research is needed. This project also provides a link between the concept of a "gatekeeper" and the ability to define this role in social network terms. A "social network" perspective on the "gatekeeper" role is not explicitly explored in current literature and is worthy of further attention.

Research has also been undertaken to explore the relationships between social networks [90] and formal organizational structures in NPD, either implicitly [e.g., through mapping out information flows during product development (Eppinger [40])] or explicitly (Cross *et al.* [66], Reagans *et al.* [50]). The interventions derived from analyzing networks in this study did not result in changing the team's formal organizational structure, but reviewing the team's networks highlights a number of "hub" actor nodes lying outside the team who may have benefited from inclusion in the formal team structure. The use of social network analysis as the basis for NPD team structures would benefit from further research attention.

D. Implications for Practitioners

One of the "by-products" of an action-research investigation is the development of a codified embodiment of research learning in a tool that can be used by practitioners. The sequencing of activities for the tailored approach to social network analysis that was developed in Section V is shown in Fig. 10. This could be used by other practitioners to improve the performance of their NPD teams. The tool could be used both at a team's inception and then reused if significant changes take place in the

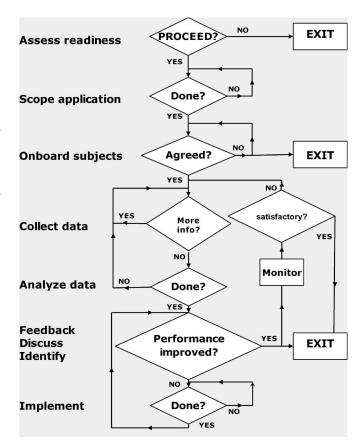


Fig. 10. Sequencing of activities for the tailored approach to social network analysis.

project's social network (e.g., the arrival of new team members) or if the team's performance appears to be degrading.

Practitioners could gather information from NPD team members on their project relationships using similar data collection instruments and processes as those expounded in Section V-A. They could use this data to create social network maps for their NPD teams similar to those developed for GKN Aerospace and TRW ASG (see Figs. 5–8). They could, then, analyze these maps using the articulations of network strength and centrality illustrated in Table II and could identify potential performance-enhancing interventions. The type of interventions includes changes to both formal and informal organizational characteristics that are also discussed in Table II. (In the case-studies undertaken in this investigation, no change was made to formal team organization structures: instead, teams concentrated on changing the nature and number of their relationships with key stakeholders.)

The experience of the action-research investigations, however, indicates that simply following these stages would not be sufficient for a practitioner to insure success in his or her endeavors. Without assessing the "organizational tolerance" for disclosing information regarding social networks, and without facilitating that disclosure from the targeted NPD teams, any attempt to map and shape social networks has the potential to be fruitless. A number of additional steps need to be performed by practitioners before application of the managerial tool, as outlined later.

1) Assessing Readiness: Consideration should be given to the readiness of the organization to participate in social network analysis. Readiness needs to be assessed in terms of the organizational culture and the availability of the resources and people to perform the analysis. The organizational culture needs to be open and supportive and encourage information sharing. The organization not only needs to commit to the time required from NPD team participants to map and analyze their networks, it also needs to have people available to fill specialist roles. The availability of a committed *champion*, a driver of the process at an appropriate level from within the organization, is of paramount importance. So too is the availability of a facilitator or deployer of the tailored approach. The deployer needs to have the skills to facilitate the application and to inspire trust. Ideally, the deployer would be external to the organization to guarantee impartiality and the integrity of the data handling elements.

The organization also needs to be happy with the level of confidentiality that is required to convince individual participants to contribute their networks. This data needs to remain confidential to the deployer and should not be disclosed to any part of the organization, even the champion, without the express permission of the contributing individual. Network information gained in the data collection process needs to be anonymised by the deployer before the analysis is undertaken.

- 2) Scoping the Application: The deployer and champion jointly will need to scope the tool before its application. Where the deployer is unfamiliar with the organization, he or she will need to gather background information and place the purpose for application of the process, the symptoms, and the perceived causes into context. The participant NPD teams will need to be identified insuring that their performance has the potential for improvement through the application of the tool.
- 3) Onboarding the NPD Team: Assessing the readiness of the organization to apply the tool is a necessary but not a sufficient activity to insure success. The deployer and the champion need to *onboard* the selected NPD teams, i.e., to give the team sufficient confidence in the integrity and utility of the analysis process so that team members are prepared to share their network data. Onboarding will need to take place in a face-to-face situation between the deployer, the champion, and the NPD team members. The onboarding activity would need to emphasize the confidentiality of the NPD team members' individual responses and the separate affiliation of the tool process from any other management agenda. Participants need to be reassured that their identifiable personal data will not be disclosed to any other individual other than the deployer without that individual's express permission. Onboarding would also need to explain how the data provided by the participants would be used and the types of performance improvement (to the individual, the team, and the organization) that could ensue. During this activity, the presence of the "champion" would emphasize the importance given by the organization to the process, but care would need to be taken to avoid individuals feeling "press-ganged" into participating. Onboarding can be used to further refine the preparation for applying the tool through the validation of the data collection tools with the NPD team and the clarification of the terminology used.

If these activities are undertaken prior to data collection, the risks associated with exposing problematic relationships are reduced. If the organization is judged not to be ready for this type of approach, or it proves impossible to get the team "onboarded," then it is highly unlikely that practitioners will be able to successfully use social network analysis to improve NPD performance.

The successful implementation of interventions identified by the teams during the analysis phase will be dependant on the change management abilities of the team and the champion. Commitment to implementing this intervention will hopefully be high, however, due to their codevelopment with the champion and team.

E. Further Research

Given the limited extendibility of the results of this investigation, the first step in further research would be to establish whether the analysis of NPD team's social networks yields insights and interventions that can contribute to improving team relationships and performance in other contexts. The tailored approach to social network analysis developed in this investigation could be applied in other companies and sectors that participate in complex product development.

Other approaches could be taken to develop the work of this investigation.

- 1) Cultural Sensitivity: The NPD team members in this investigation predominately related to one national culture. The willingness to contribute network data and the acceptability of rating relationships may be culturally sensitive. Further work could be undertaken to establish whether mapping and analyzing social networks to generate insights and actions could be used cross-culturally. This is especially important given the growth of global product development teams.
- 2) Social Network Presentations: The NPD team members in this investigation came predominately from a technical background. This may have made graphical presentations of social network data the most easy for them to assimilate and comment upon. People from other disciplines may have preferences for other formats (e.g., mathematical matrices, pictorial, etc.). Since the ability of the NPD team members to grasp the dimensions and characteristics of the network in question is critical to their ability to generate insights and interventions, research could be undertaken to establish the most effective formats for network data.
- 3) Further Mathematical Analysis of Networks: The use of more sophisticated mathematical techniques may yield greater insights into NPD team behavior. Concepts of network symmetry or network equivalence, if linked with empirical evidence from the behavior of real NPD networks, could lead to the development of successful network "archetypes" that could be used as templates for other NPD teams.

Incentives to develop the work of this investigation further lie in the potential for analyzing social networks to improve NPD team performance. This paper began by commenting on the fruitful relationship between academics and practitioners in the identification of the cross-functional team as the preeminent form of organizational structure for NPD. Arguably, the same

interplay of ideas will be needed in order to develop teams even further to match the continuing pressures on NPD performance. This investigation suggests that collaborations to extend the performance of NPD teams by considering their social network may show similar opportunities for success.

REFERENCES

- E. F. McDonough, "An investigation into the factors contributing to the success of cross-functional teams," *J. Prod. Innov. Manage.*, vol. 17, no. 3, pp. 221–235, 2000.
- [2] S. D. Eppinger and V. K. Salminen, "Patterns of product development interactions," presented at the Int. Conf. Eng. Des., Glasgow, U.K., Aug. 21–23, 2001.
- [3] E. Rosenthal, "Social networks and team performance," *Team Perform. Manage.*, vol. 2, no. 2, pp. 288–301, 1996.
- [4] J. Huang and S. Newell, "Knowledge integration processes and dynamics within the context of cross-functional projects," *Int. J. Project Manage.*, vol. 21, no. 3, pp. 167–176, 2003.
- [5] E. U. Bond, B. A. Walker, M. D. Hutt, and P. H. Reingen, "Reputational effectiveness in cross-functional working relationships," *J. Prod. Innov. Manage.*, vol. 21, no. 1, pp. 44–61, 2004.
- [6] J. S. Mouton, R. R. Blake, and B. Fruchter, "The reliability of sociometric measures," *Sociometry*, vol. 18, no. 1, pp. 7–48, 1955.
- [7] C. Hayashi, "Note on sampling from a sociometric pattern," Ann. Inst. Stat. Math., vol. 9, no. 1, pp. 49–52, 1957.
- [8] S. Wasserman and K. Faust, Social Network Analysis: Methods and Applications, 2nd ed. Cambridge, U.K.: Cambridge University Press, 1996.
- [9] D. Krackhardt and J. R. Hanson, "Informal networks: The company behind the chart," *Harv. Bus. Rev.*, vol. 71, no. 4, pp. 104–111, 1993.
- [10] A. H. Cole, "Underground social capital," Bus. Hist. Rev., vol. 42, no. 4, pp. 482–493, 1968.
- [11] J. Nahapiet and S. Ghoshal, "Social capital, intellectual capital, and the organizational advantage," *Acad. Manage. Rev.*, vol. 23, no. 2, pp. 242– 266, 1998
- [12] P. S. Adler and S.-W. Kwon, "Social capital: Prospects for a new concept," Acad. Manage. Rev., vol. 27, no. 1, pp. 17–40, 2002.
- [13] A. Inkpen and E. Tsang, "Social capital, networks, and knowledge transfer," Acad. Manage. Rev., vol. 30, no. 1, pp. 146–165, 2005.
- [14] S. E. Seibert, M. L. Kraimer, and R. C. Liden, "A social capital theory of career success," *Acad. Manage. J.*, vol. 44, no. 2, pp. 219–237, 2001.
- [15] R. S. Burt, "The contingent value of social capital," *Adm. Sci. Q.*, vol. 42, no. 2, pp. 239–266, 1997.
- [16] W. Tsai and S. Ghoshal, "Social capital and value creation: The role of interfirm networks," *Acad. Manage. J.*, vol. 46, no. 4, pp. 464–476, 1998.
- [17] P. R. Lawrence and J. W. Lorsch, Organisation and Environment: Managing Differentiation and Integration. Boston, MA: Harvard University, 1967.
- [18] E. Booz, J. Allen, and C. Hamilton, New Product Development in the 1980s, New York: Booz, Allen and Hamilton, 1982.
- [19] J. R. Galbraith, Organisation Design. Reading, MA: Addison-Wesley, 1977.
- [20] H. Mintzberg, The Structuring of Organisations. Englewood Cliffs, NJ: Prentice-Hall, 1979.
- [21] G. Pahl and W. Beitz, Engineering Design. London, U.K.: The Design Council, 1984.
- [22] W. E. Souder and A. K. Chakravarty, "The R&D/marketing interface: Results from an empirical study of innovation projects," *IEEE Trans. Eng. Manage.*, vol. 25, no. 4, pp. 88–93, Apr. 1978.
- [23] S. C. Wheelwright and K. B. Clark, Revolutionising Product Development: Quantum Leaps in Speed, Efficiency and Quality. New York: Macmillan, 1992.
- [24] C. Erhorn and J. Stark, Competing by Design: Creating Value and Market Advantage in New Product Development. Essex Junction, VT: Oliver Wight, 1994.
- [25] M. A. Cohen, J. Eliashberg, and T. H. Ho, "An analysis of several new product performance metrics," *Manuf. Serv. Oper. Manage.*, vol. 2, no. 4, pp. 337–349, 2000.
- [26] S. D. Eppinger, C. Fine, and K. T. Ulrich, "Interdisciplinary product design education," *IEEE Trans. Eng. Manage.*, vol. 37, no. 4, pp. 301–305, Nov. 1990.

- [27] V. Krishnan and K. T. Ulrich, "Product development decisions: A review of the literature," *Manage. Sci.*, vol. 47, no. 1, p. 1, 2001.
- [28] S. L. Brown and K. M. Eisenhardt, "Product development—Past research, present findings and future directions," *Acad. Manage. Rev.*, vol. 20, no. 2, pp. 343–378, 1995.
- [29] A. K. Chakravarty, "Overlapping design and build cycles in product development," Eur. J. Oper. Res., vol. 134, no. 2, pp. 164–196, 2001.
- [30] S. Novak and S. D. Eppinger, "Sourcing by design: Product complexity and the supply chain," *Manage. Sci.*, vol. 47, no. 1, pp. 189–204, 2001
- [31] H. Ernst, "Success factors of new product development: A review of the empirical literature," *Int. J. Manage. Rev.*, vol. 4, no. 1, pp. 1–40, Mar. 2002.
- [32] K. T. Ulrich and S. D. Eppinger, Product Design and Development, 2nd ed. New York: McGraw-Hill, 2000.
- [33] E. J. Nijssen, A. R. L. Arbouw, and H. R. Commandeur, "Accelerating new product development: A preliminary empirical test of a hierarchy of implementation," *J. Prod. Innov. Manage.*, vol. 12, no. 2, pp. 99–109, 1995.
- [34] R. G. Cooper and E. J. Kleinschmidt, "An investigation into the product development process: Steps, deficiencies and impact," *J. Prod. Innov. Manage.*, vol. 3, no. 2, pp. 71–85, 1986.
- [35] V. Krishnan, S. D. Eppinger, and D. E. Whitney, "A model-based framework to overlap product development activities," *Manage. Sci.*, vol. 43, no. 4, pp. 437–451, 1997.
- [36] R. G. Cooper, Winning at New Products, 2nd ed. Reading, MA: Addison-Wesley, 2001.
- [37] X. M. Song, R. J. Thieme, and X. Jinhong, "The impact of cross-functional joint involvement across product development stages: An exploratory study," *J. Prod. Innov. Manage.*, vol. 15, pp. 289–303, 1998.
- [38] R. G. Cooper and E. J. Kleinschmidt, "New products: What separates winners from losers?," *J. Prod. Innov. Manage.*, vol. 4, pp. 169–184, 1987.
- [39] J. R. Hauser and D. P. Clausing, "The house of quality," *Harv. Bus. Rev.*, vol. 66, no. 3, pp. 63–73, 1988.
- [40] S. D. Eppinger, "Innovation at the speed of information," *Harv. Bus. Rev.*, vol. 79, no. 1, pp. 149–158, 2001.
- [41] K. T. Ulrich and D. E. Ellison, "Holistic customer requirements and the design select decision," *Manage. Sci.*, vol. 45, no. 5, pp. 642–658, 1999.
- [42] G. Pahl and W. Beitz, Engineering Design: A Systematic Approach. New York: Springer, 1988.
- [43] D. G. Ancona and D. Caldwell, "Beyond boundary spanning: Managing external dependence in product development teams," *J. High Technol. Manage. Res.*, vol. 1, no. 2, pp. 119–135, 1991.
- [44] H. Mintzberg, D. Dougherty, J. Jorgensen, and F. Westley, "Some surprising things about collaboration—Knowing how people connect makes it work better," *Organ. Dyn.*, vol. 25, no. 1, pp. 60–71, 1996.
- [45] L. Gales and D. Mansour-Cole, "User involvement in innovation projects: Toward an information processing model," *J. Eng. Technol. Manage.*, vol. 12, no. 1, pp. 77–109, 1995.
- [46] E. F. McDonough and K. B. Kahn, "Using 'hard' and 'soft' techniques for global new product development," R&D Manage., vol. 26, no. 3, pp. 241–254, 1996.
- [47] G. Barczak, E. F. McDonough, N. Athanassiou, and F. Spital, "Capabilities for global new product development: The role of networks and social capital," in *Proc. Am. Mark. Assoc. Conf. Chicago* 2003, vol. 14, pp. 217–232.
- [48] S.-H. Lee, P.-K. Wong, and C.-L. Chong, "Human and social capital explanations for R&D outcomes," *IEEE Trans. Eng. Manage.*, vol. 52, no. 1, pp. 59–81, Feb. 2005.
- [49] M. A. McFayden and A. A. Cannella Jr., "Social capital and knowledge creation: Diminishing returns of the number and strength of exchange relationships," *Acad. Manage. J.*, vol. 47, no. 5, pp. 735–757, 2004.
- [50] R. Reagans, E. W. Zuckerman, and B. McEvily, "How to make the team: Social networks vs. demography as criteria for designing effective teams," *Adm. Sci. Q.*, vol. 49, no. 1, pp. 101–126, 2004.
- [51] H. M. Fischer and T. G. Pollock, "Effects of social capital and power on surviving transformational change: The case of initial public offerings," *Acad. Manage. J.*, vol. 47, no. 4, pp. 463–470, 2004.
- [52] H. Oh, M.-H. Chung, and G. Labianca, "Group social capital and group effectiveness; The role of informal socializing ties," *Acad. Manage. J.*, vol. 47, no. 6, pp. 860–873, 2004.
- [53] H.-L. Yang and J. H. Tang, "Team structure and team performance in IS development: A social network perspective," *Inf. Manage.*, vol. 41, no. 3, pp. 335–351, 2004.

- [54] M. Hoegl, K. P. Parboteeah, and C. L. Munson, "Team-level antecedents of individuals knowledge networks," *Decis. Sci.*, vol. 34, no. 4, pp. 731– 771, 2003.
- [55] M. K. Ahuja, D. F. Galletta, and K. M. Carley, "Individual centrality and performance in virtual R&D groups: An empirical study," *Manage. Sci.*, vol. 49, no. 1, pp. 21–38, 2003.
- [56] M. Bresnen, L. Edelman, S. Newell, H. Scarborough, and J. Swan, "Social practices and the management of knowledge in project environments," *Int. J. Proj. Manage.*, vol. 21, no. 3, pp. 157–166, 2003.
- [57] J. N. Cummings, "Work groups, structural diversity, and knowledge sharing in a global organization," *Manage. Sci.*, vol. 50, no. 3, pp. 352–364, 2004
- [58] N. Athanassiou and D. High, "The impact of the top management team's international business experience on the firm's internationalisation: Social networks at work," *Manage. Int. Rev.*, vol. 42, no. 2, pp. 157–182, 2002.
- [59] A. Mehra, M. Kilduff, and D. J. Brass, "The social networks of high and low self-monitors: Implications for workplace performance," *Adm. Sci.* Q., vol. 46, no. 1, pp. 121–146, 2001.
- [60] S. P. Mead, "Using social network analysis to visualize project teams," Proj. Manage. J., vol. 32, no. 4, pp. 32–38, 2001.
- [61] R. Reagans and E. W. Zuckerman, "Networks, diversity, and productivity: The social capital of corporate R&D teams," *Organ. Sci.*, vol. 12, no. 4, pp. 502–517, 2001.
- [62] R. T. Sparrowe, R. C. Liden, S. J. Wayne, and M. L. Kraimer, "Social networks and the performance of individuals and groups," *Acad. Manage. J.*, vol. 44, no. 2, pp. 316–325, 2001.
 [63] M. T. Hansen, "The search-transfer problem: The role of weak ties in
- [63] M. T. Hansen, "The search-transfer problem: The role of weak ties in sharing knowledge across organization subunits," *Adm. Sci. Q.*, vol. 44, no. 1, pp. 82–111, 1999.
- [64] J. Tidd, "Development of novel products through intraorganizational and interorganizational networks," *J. Prod. Innov. Manage.*, vol. 12, no. 4, pp. 307–322, 1995.
- [65] R. Florida, R. Cushing, and G. Gates, "When social capital stifles innovation," *Harv. Bus. Rev.*, vol. 80, no. 8, p. 20, Aug. 2002.
- [66] R. Cross, S. P. Borgatti, and A. Parker, "Making invisible work visible: Using social network analysis to support strategic collaboration," *Calif. Manage. Rev.*, vol. 44, no. 2, pp. 25–46, 2002.
- [67] K. Lewin, "Action research and minority problems," J. Soc. Issues, vol. 2, no. 4, pp. 34–36, 1946.
- [68] T. F. Burgess, N. E. Shaw, and C. de Mattos, "Organisational self-assessment and the adoption of managerial innovations," *Int. J. Prod. Perform. Manage.*, vol. 54, no. 2, pp. 98–112, 2005.
- [69] V. R. Prybutok and R. Ramasesh, "An action-research based instrument for monitoring continuous quality improvement," Eur. J. Oper. Res., vol. 166, no. 2, pp. 293–309, 2005.
- [70] C. Meehan and D. Coghlan, "Developing managers as healing agents in organizations: A co-operative inquiry approach," Syst. Pract. Action Res., vol. 17, no. 5, pp. 407–423, 2004.
- [71] D. Parker and A. Mobey, "Action research to explore risk in project management," *Int. J. Prod. Perform. Manage.*, vol. 53, no. 1, pp. 18–32, 2004.
- [72] R. Menda, "The role of a manufacturing audit in crafting the production system," *Int. J. Oper. Prod. Manage.*, vol. 24, no. 9, pp. 929–943, 2004.
- [73] R. N. Rapoport, "Three dilemmas in action research," Hum. Relat., vol. 29, no. 6, pp. 459–513, 1970.
- [74] J. Gill and P. Johnson, *Research Methods for Managers*. London, U.K.: Paul Chapman, 1991.
- [75] C. Huxham and S. Vangen, "Researching organizational practice through action research: Case-studies and design choices," *Organ. Res. Methods*, vol. 6, no. 3, pp. 383–403, 2003.
- [76] A. W. S. Technology, "Measure for measure," Aviat. Week Space Technol., vol. 162, no. 23, pp. 62–64, 2005.
- [77] SBAC, "SBAC Annual Review," London, U.K., Rep. SBAC-COM-RPT-05-1009(1.0), 2005.
- 05-1009(1.0), 2005. [78] "Getting it together?," *The Economist*, vol. 41, pp. 41–53, Jul. 18, 2002.
- [79] R. Reagans, "Preferences, identity and competition, predicting tie strength from demographic data," *Manage. Sci.*, vol. 51, no. 9, pp. 1374–1383, 2005
- [80] C. Judd, E. Smith, and L. Kidder, Research Methods in Social Relations, 6th ed., New York: Holt, Rinehart and Winston, 1991.
- [81] J. C. Nunnally, *Psychometric Theory*, 2nd ed. New York: McGraw-Hill, 1978
- [82] D. Levin and R. Cross, "The strength of weak ties that you can trust: The mediating role of trust in effective knowledge transfer," *Manage. Sci.*, vol. 50, no. 11, pp. 1477–1491, 2004.

- [83] M. T. Hansen, M. L. Mors, and B. Lovas, "Knowledge sharing in organizations: Multiple networks, multiple phases," *Acad. Manage. J.*, vol. 48, no. 5, pp. 776–793, 2005.
- [84] M. L. Tushman, "Special boundary roles in the innovation process," *Adm. Sci. Q.*, vol. 22, no. 4, pp. 587–605, 1977.
- [85] A. Pettigrew, "Information control as a power resource," *Sociology*, vol. 6, pp. 187–204, 1972.
- [86] R. T. Keller and W. E. Holland, "Boundary-spanning roles in a research and development organization: An empirical investigation," *Acad. Man-age. J.*, vol. 18, no. 2, pp. 388–393, 1975.
- [87] P. R. Carlisle, "A pragmatic view of knowledge and boundaries: Boundary objects in new product development," *Organ. Sci.*, vol. 13, no. 4, pp. 442– 455, Jul.–Aug. 2002.
- [88] J. Hoffman, M. Hoelscher, and K. Sherif, "Social capital, knowledge management and sustained superior performance," *J. Knowl. Manage.*, vol. 9, no. 3, pp. 93–101, 2005.
- [89] M. Subramaniam and M. Youndt, "The influence of intellectual capital on the types of innovative capabilities," *Acad. Manage. J.*, vol. 48, no. 3, pp. 450–461, 2005.
- [90] H. Mintzberg and L. Van der Heyden, "Organigraphs: Drawing how companies really work," *Harv. Bus. Rev.*, vol. 77, no. 5, pp. 87–94, 1999.



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