A Metric for Collaborative Networks

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ABSTRACT

The objective of this paper is to provide a metric that could be used to define success in a collaborative network. The metric shows three kinds of measurements that might influence the success of collaborative networks. This paper contributes to the body of knowledge by developing a methodology for measuring partners' contribution, involvement and outcome in the collaborative network as a system within IDEF0 functional modelling. The contribution measurement uses Analytical Hierarchy Process (AHP) approach to measure *partners' contribution.* Likert scale is also applied to measure *the health of the relationships* based on key performance indicators of relationship attributes. Analytical with mathematical approach is employed to measure the *partners' outcome* of the collaborative network.

This paper presents application of the metric into a single collaborative network. The fact that this collaboration has been engaged for more than a year in order to develop a particular product, but it was difficult to identify all outcomes precisely.

KEYWORDS

Collaboration, Contribution, Health of relationship, Outcome

INTRODUCTION

Since the numbers of collaborative initiatives are increasing, much attention has been devoted to issues surrounding success and failure factors of collaborative enterprises. Early studies have identified the key drivers of success for example: effective support from senior management, a clear sense of mission and objectives, a strong leadership team with personal commitment (Gomes-Casseres, 1999; Horvath 2001, McLaren et al. 2002), Individual Excellence of partners, Importance to fits strategic goals of each partner, Interdependence among partners, Investment as tangible commitment of partners, Internalization, Information sharing, Integration at several levels, Institutionalization, and Integrity (nine I's of Kanter, 1994). Earlier publications have also identified the reasons

behind the failures, such as: difficulties in participants' relationship, participants' dissatisfaction with outcome and/or organisation structure of the collaboration (Kanter, 1994; Das and Teng, 1998; Kalmbach and Roussel, 1999; Huxham and Vangen, 2000; Child, 2001).

Regardless of the fact that considerable works have been accomplished in order to increase collaboration success and to eliminate failure factors, an understanding of characteristics associated with collaborative success and failure and its metric is lacking. For example, since it is believed that companies join a collaborative network to contribute different resources and then derive benefits based on their contribution (Hunt and Morgan, 1994; Das and Teng, 1998; Jolly, 2004), existing literatures do not explain *how contribution could be measured* and *how to ensure that each partner gain from collaboration.* Furthermore, much works in the collaboration area argued that to maintain collaboration, partners have to develop their relationship behaviour through improve coordination between management teams, set up appropriate working process, maintain commitment and trust among partners (Huxham and Vangen, 2000; Elmuti and Kathawala, 2001). However, existing works have not explained *how to evaluate the interaction and relationship between partners.* These realities highlight the need for research that can provide insight into factors underlying the metrics in a collaborative network.

In order to develop collaborative metric analytically, a collaborative network is observed as a system which consists of input, activity, mechanism, control and output as in Idef0 model. From strategic standpoint, the issue is how partners can measure the collaborative attributes of the system. In our view, measuring input is an attempt to confirm what resources participants contribute into a collaborative network. Measuring activity process is an effort to distinguish healthy collaborative networks from unhealthy ones. Measuring output is an attempt to determine values gained by key stakeholders through collaborative networks.

This paper presents a model with three kinds of measurements (i.e. contribution, health and outcome) that might influence the success and failure of collaborative networks. The Analytical Hierarchy Process (AHP) is applied to measure *partners' contribution* on five

value generators i.e. financial, physical, human capital, relational capital and organisational capital. *The health of the relationships* based on key performance indicators of five relationships attributes (i.e. commitment, coordination, trust, communication and conflict resolution) is measured using Likert scale. The overall *outcome of collaborative network* is measured using mathematical approach. These outcomes comprise of internal and external values and they are measured aggregately in order to have one single measurement.

The issue of terminology is addressed by summarising extant literature under four concepts:

- Collaboration and collaborative networks
- Idef0
- Analytic Hierarchy Process (AHP)
- Value and value generator

RESEARCH METHOD

This research is constructive research in nature (Kasanen et al., 1993 and Kaplan, 1998). The sequencing of phases includes the Review, Constructing, Testing and Description.

At first, the relevant literature is studied in brief to develop a better understanding of the terminology using in the metric of collaborative networks. Based on this literature, a Metric is constructed and then tested through case study. The outcome of the case study was discussed with the participants to assess usability and usefulness of the metric for participants in turn to generate conclusions.

COLLABORATION AND COLLABORATIVE NETWORK ORGANISATION

Literally, collaboration means working together for mutual benefits. Considering inter-organisational relationship, collaboration is a term, which depicts the closest relationships between partners (Golicic et al., 2003). Nowadays, several companies collaborate in a network to share data and information, systems, risks and benefits. By definition a collaborative network organisation consists of two or more companies that bring tangible

and intangible resources into organisations (Wernerfelt, 1984). As a system, partners companies in a collaborative network organisation can be identified as a relatively interdependent part or subsystem.

The following sections provide a brief discussion of four widely accepted types of collaborative network organisation. We put emphasis on criterion that how to differentiate among them is based on what the participants' bring and share in a network. How to measure things that participants bring and share in the network is the main focus of this paper.

Supply Chains

According to Christopher (1992), supply chain is the network of organizations interlinking suppliers, manufacturers and distributors in the different processes and activities that produce value in the form of products and services delivered to end consumer. This definition has been updated by the Supply Chain Council (1997) as "every effort involved in producing and delivering a final product or service, from the supplier's supplier to the customer's customer" (www.supply-chain.org). In this end-to-end process, all channels in the supply chain can bring or share data, information, and resources with partners in order to achieve their objectives. However, it is not common to share risks and benefits among participants in a supply chain.

Extended enterprises

According to Childe (1998) an extended enterprise is "a conceptual business unit or system that consists of a purchasing company and suppliers who collaborate closely in such a way as to maximise the returns to each partner". Furthermore the extended enterprise is a philosophy where member organisations strategically combine their core competencies and capabilities to create a unique competency (Bititci et al., 2004). In extended enterprises, people across a number of organisations participate in the decision-making process (O'Neill and Sackett, 1994; Kochhar and Zhang, 2002). Sharing data, information, resources, and risks are commonplace in an extended enterprise in order to achieve mutual benefits amongst participants.

Virtual enterprises

A virtual enterprise is considered as a temporal case of an extended enterprise. The virtual enterprise is a dynamic partnership among companies that can bring together complementary competencies needed to achieve a particular business task, within a certain period of time (Kochhar and Zang, 2002). According to Bititci et al. (2004), Virtual Enterprise is "a *temporal* knowledge-based organization, which uses the distributed capabilities, competencies and intellectual strengths of its members to gain competitive advantage to maximize the performance of the overall virtual enterprise. In virtual enterprise, participants usually shared data, information, resources, risks, and benefits".

Clusters

A cluster could be defined as a network of companies, their customers and suppliers, including materials and components, equipment, training, finance and so on (Carrie, 1999). Clusters are also defined as geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition. They include, for example, suppliers of specialised inputs such as components, machinery, and services, and providers of specialised infrastructure (Porter, 1998). In clusters, participants usually share data, information, resources and sometimes risks.

IDEF0

IDEF0 (IDEF-zero) is one of the IDEF families that widely accepted as one of the process analysis tools. IDEF stands for ICAM DEFinition (ICAM is the acronym of Integrated Computer-Aided Definition). IDEF is developed under the sponsorship of the US Air-force by Soft-Tech Inc. to explain the information and the organisation structure of a complex manufacturing system (Pandya et al., 1997). According to Ross and Schoman (1977), the IDEF0 modeling is used to analyse whole systems as a set of interrelated activities or functions.

There are five elements of the IDEF0 model as displayed in Figure 1 (Edgerton, 2002). This figure shows the IDEF0 basic model that might be modified in different applications. The activity (or process) of the basic model is represented by the box. Inputs are shown as arrows entering the left side of the activity box, while the outputs are shown as exiting arrows on the right hand side of the box. The arrows flowing into the top portion of the box represent constraints or controls of the activities. Mechanisms are displayed as arrows entering from the bottom of the box. These arrows also defined as ICOM's, the acronym of Inputs, Controls, Outputs and Mechanisms. According to Pandya et al. (1997) the IDEF0 should be easy to be used to understand how the model works because it only consists of few symbols, just arrows and boxes.

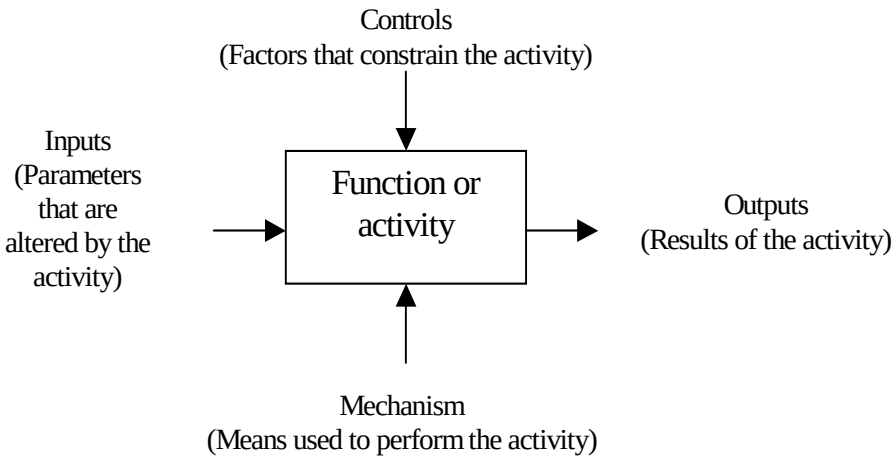

Figure 1 Basic IDEF0

Application of IDEF0 into a collaborative network system is shown in Figure 2. This figure shows a structured representation of the functions and processes in a collaborative network. Inputs for creating value activities in the collaborative network are contribution resources from partners. Outputs of the activities are added value for stakeholders. Mechanisms to the activities are inter-organisational attributes, and control for the activities is collaboration agreements (legal) between partners. Inputs of the collaborative network are transformed into defined outputs using the relationships attributes as mechanism under the formal agreements as constraints of the network. In this case, IDEF0 become a suitable tool for visualisation of a complex collaboration system.

AHP

AHP is one of the multi-criteria decision aids. The AHP structures the decision problem in levels, which correspond to one; understanding of the situation: goals, criteria, sub criteria, and alternatives. By breaking problems into levels, the decision maker can focus on smaller sets of decisions (Saaty, 1980). From paired comparisons made on the basis of the user's beliefs, available facts, attitudes and other attributes, a scale of relative priorities is derived for elements in a group that share a common property in the hierarchy. The AHP derives scales for each level, and these are transferred into the ratio scales, which are made corresponding to the hierarchical weighing process. The expressions of qualitative judgments and preferences are expressed in appropriate linguistic designations associated with the numerical scale values in order to get a meaningful outcome.

The AHP tool attracted much criticism from people who have questioned its underlying axioms, inconsistencies imposed by 1 to 9 scale and meaningfulness of responses to questions (see for example, Watson and Freeling, 1982). Further, Belton and Gear (1983 and 1985) revealed that AHP could suffer from rank reversal. Belton and Gear have also argued that the AHP lacks of a firm theoretical basis. According to Dyer (1990a and 1990b) “application of the AHP based on the principle of hierarchic composition produced rankings based on the consistent responses of a decision maker that cannot be shown to be consistent with his or her preferences”.

The defences of these criticisms have been provided for example by Saaty and Vargas (1984), Harker and Vargas (1987 and 1990) and then Saaty (1990). They presented theoretical works and examples of the application of the AHP. They remarked that the AHP is based upon a firm theoretical foundation. They argued with examples in the literature and the day-to-day operations of various fields (e.g. in business and governmental) that the AHP is a viable and usable decision-making tool.

Even though it has attracted some controversy; the application of the AHP as decision aid in various field are continued (see for example Gilleard and Yat-lung, 2004). In this model

the AHP was selected due to its simplicity and ease of implementation resulting from the user-friendly software (Lee et al, 1995; Goodwin and Wright, 2004) and inclusion of qualitative and quantitative factors.

AHP can also be applied for establishing parameter weights in the hierarchical structure of environmental effects at each level. A scale of importance estimation has verbal judgements ranging from equal to extreme importance: equal, moderately, strong, very strong and extremely important. The numerical judgments corresponding to these linguistic descriptions are (1,3,5,7,9), with compromises (2,4,6,8) between these judgments (Saaty, 1980). The AHP uses the principal eigenvector (weight vector) to solve the problem of deriving the ensemble-resultant weights from the weight ratio matrix.

VALUE AND VALUE GENERATOR

The terminology of value has been growing exponentially by its adoption various fields (e.g. in economics and finance, marketing management, service management, strategic management, operation management and engineering). Each field is taking different approaches. Consequently, the literature on value has become extensive (Martinez-Hernandez, 2003).

Value is defined by Oxford advanced learner's dictionary (2002) in two meanings, as a noun and a verb. As a noun value means how much something is worth in money or other goods for which it can be exchanged or how much something is worth compared to its price. As a verb to value means to think that somebody or something is important. Mouritsen et al (2001) argue that in the financial accounting, value means assigning numbers mostly based on historical cost of acquisition. They also stated that in finance theory, value is a matter of predicting the future cash flows of the firm and discounting them to the present. While in an intellectual capital point of view value is like in finance approach, except that it does not present the firm's net present value.

Previous works have also defined value in different views; for example, value can be regarded as a trade-off between benefits and sacrifices (Flint et al, 1997). Few cases define value in business markets monetarily (e.g. Anderson and Narus, 1999) while others use a

broader value definition, which also includes non-monetary revenues, such as competence, market position, and social rewards. Furthermore, Zeithaml (1988) suggest four possible definitions of value:

1. Value is low price
2. Value is concerned with what the customer is looking for in the product, i.e. benefits that are a subjective measure of the usefulness or the satisfaction of needs resulting from consumption.
3. Value is the quality the customer gets for the money paid, i.e. a specific trade-off. In this definition, price takes precedence over quality, which is consistent with a number of definitions
4. Value is what the customer gets for what he gives.

Martinez-Hernandez (2003) defines value as wealth, i.e. company's value (wealth of company) consists of: prestige over competitors, gain markets, margin, and company developed. Whilst customers' values consist of: image, total care, quality performance, low prices and new product.

Even though, definition of value is very broad, within the context of this paper, we understand *value as: the trade-off between multiple benefits (monetary and non monetary) and sacrifices gained for stakeholders of a collaborative network organisation*. These values can be differentiated to the values for employees (e.g. financial benefits, safety satisfaction), customers (e.g. on time delivery and cheaper prices), communities (e.g. economic activities) and shareholders/partners (e.g. profits).

A value generator is "some thing" belonging to individual company, which is used to create more value for collaborative enterprise. Each member of a collaborative network organisation might contribute different value generators in order to create more values for a network's stakeholders. Das and Teng (1998) stated that participants in a collaborative organisation could contribute in four critical resources, i.e. physical, financial, technology and managerial resources. Gulati and Singh (1998) believe that partners bring capital, technology or partner's specific assets, while Edvinsson (1997) stated that intellectual capital as important as financial capital in providing truly sustainable earnings for companies. In addition, different work of Edvinsson and Malone (1997), and also Mouritsen

et al., (2001) declared intellectual capital as a significant factor in increasing companies' values. Intellectual capital consists of human capital, relational capital and organisational capital. Human capital is the abilities that employees bring to a company. Relational capital is representative's value of an organization's relationships with its customers. Organisational capital or structural capital institutionalises an employee as a company asset with the use of the following tools: databases, computer networks, patents, and so on (Pablos, 2002). Due to our focus on the resources that generate values for collaborative network, we use term value generators. Value generators can be categorised into financial assets, physical assets, human capital, relational capital and organisational capital.

COLLABORATIVE METRICS

Measurement is one of the main activities of management. According to Kaplan and Norton (1996), if you cannot measure it, you cannot manage it. However, before something is measured, it must be defined, and definition should relate to the objective of the collaboration. The most important objective of collaboration is to become sustainable in a competitive environment by creating benefits for stakeholders. This is critical since measurement will affect the level of relationship among participants of the collaboration. Low level of relationships will occur if there is disagreement and/or dissatisfaction about measurement attributes, e.g. methods, criteria, target, and measurement of success. This can be accomplished by defining measures used to define success and define measurement attributes mutually among participants. Three kinds of measurements that might influence the success of collaborative networks are explored in this paper:

- Input to the collaboration, that is the contribution of each participant
- Mechanism of the collaboration, that is the health of the collaboration
- Output of the collaboration, that is the results of the collaboration activities

The position of each measure is shown in Figure 2.

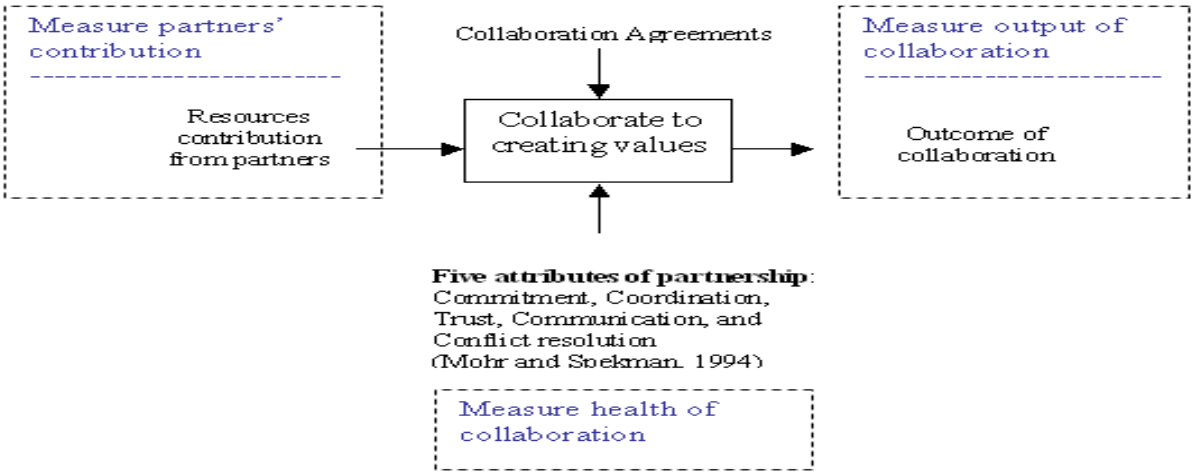

Figure 2 Interplay of element in a collaborative network

Measuring the Contribution

As outlined before, the main inputs to the creating value activities in the collaborative networks are the contribution of its partners. The problem is how to measure participants' contribution. The next section proposes a conceptual methodology to measure participants' contribution in collaborative networks.

The process of measuring contributions

Measuring the participants' contribution is a clearly defined problem, but the solution is complex. This problem involves multiple, potentially conflicting, participants' goals, and it is likely to involve a large number of factors to be considered. Therefore, the process of measuring participants' contribution is suggested to use a formal and systematic procedure in the decision making process, using one of the multi-criteria decision aids. According to Belton and Steward (2002), all problems and decisions are multi-criteria in nature; multi-criteria analysis begins when someone feels that the issue matters enough to explore the potential of formal modelling. To measure a participant's contribution in a Collaborative network we propose using AHP (Saaty, 1980).

To start the measuring process, a problem is decomposed into a multi-level hierarchical structure, as can be seen in the illustrative example in Figure 3, which is comprised of value generators and their factors. Table 1 provides examples of value generators and associated factors.

The second step is to prioritize the value generators and factors. Many tools have been developed for this purpose (Von Winterfeldt and Edwards, 1986, and Ghiselli et al, 1971). The AHP has been used here to demonstrate the process of weighing value generators and factors in a collaborative network. All value generators and factors weighing use pair-wise comparisons with respect to the mutual objectives.

The third step is to assess the participants' contribution in each factor. In this step, partners take part in the discussion in order to make assessment about partner's contribution of each factor for the past collaboration project. Before making an assessment, partners have to define contribution rating of each factor as for example:

- Very strong contribution
- Strong contribution
- Moderate contribution
- Poor contribution
- No contribution at all

Each rating corresponds to the numerical values for example 1.00; 0.75; 0.50; 0.25 and 0.00 respectively.

The last step is to measure participants' contribution. All of the paths that lead from the top of the hierarchy to the participant performance are identified. Then all of the weights in each path are multiplied together and the results for different paths are added in order to calculate the contribution of each participant company.

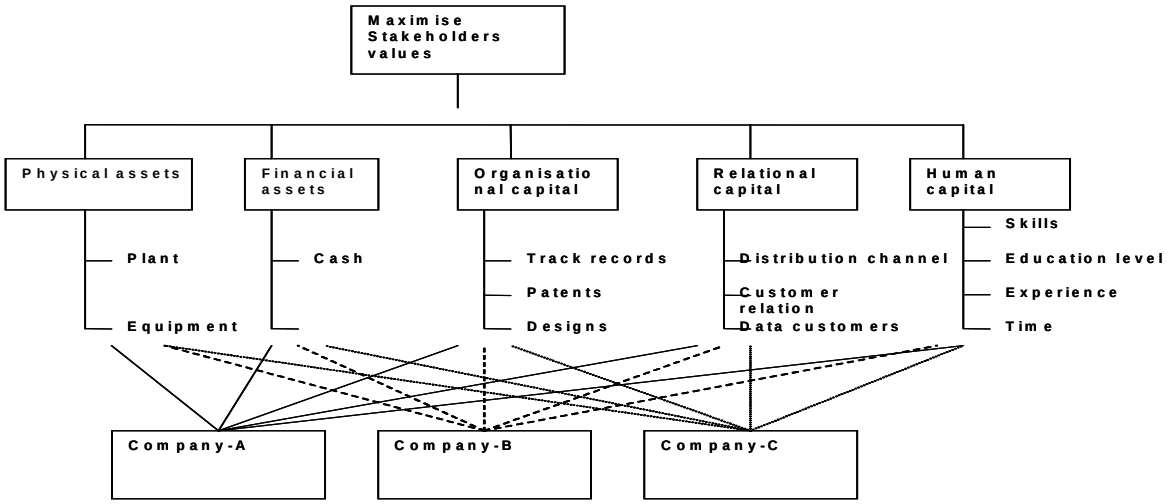

Figure 3 Hierarchy structure

Table 1 Value generators and examples of factors

Value generator	Physical assets	Financial assets	Organisational capital	Relational capital	Human capital
Factors	➢ Plant ➢ Machines used in the process ➢ Tools and equipment ➢ Transportation	Cash for: ➢ Payroll cost ➢ Administrative expenses ➢ Maintenance cost ➢ Operating cost ➢ Advertisement cost ➢ Material/stock	➢ Patents ➢ Designs ➢ Track record ➢ Data bases ➢ Systems and procedures ➢ Innovation	➢ Distribution channel ➢ Customers Data ➢ Customer relations ➢ Brand ➢ Image ➢ Numbers of contracts	➢ Skill ➢ Education level ➢ Experience ➢ Management time ➢ Numbers of employees ➢ Employees efforts

Measuring the Health of a Collaborative Network

Generally, in every inter-organisational relationship; partners usually engage in three actions:

- Strategic decisions, e.g. decision, that are related to the governance of the relationship (Gulati and Singh, 1998).
- Managerial activities, e.g. activities that are related to the planning, organising, executing and controlling of financial resources or project risk (Nielsen and Galloway, 1994).
- Operational activities, e.g. activities that are related to the scheduling of machines and operators.

The efficiency and effectiveness of the decisions and activities will depend on how good the interaction is among partners within an organisation. Furthermore, the qualities of the interaction among partners will describe the health of the organisation.

Measuring the health of the relationships could be used to predict sustainability or potential success of a collaboration network. It is assumed that the healthier collaboration will have a longer life than the less healthy ones. To measure the health of a collaboration network we propose to use and adopt five attributes as the primary characteristics of partnership success as proposed by Mohr and Spekman (1994). Those characteristics are partnership attributes of:

- Commitment
- Coordination
- Trust
- Communication quality and participation
- The conflict resolution technique of joint problem solving.

Every collaboration network can choose its key performance indicators itself. *Key performance indicators are identified and selected by partners before formalising the collaboration*. The status of the health of the collaboration can be measured using Likert scale. Table 2 shows the example of the attributes and state of health of the collaboration. Collaborative network that aggregately has a strong or very strong statement indicates a healthy relationship.

Probably the biggest problem in implementing this metric is to get consensus among partners. Therefore, intensive discussions are needed in order to improve better understanding among partners. To help partners achieve consensus objectively, partners can implement idea advocate technique (Van Gundy, 1998). An idea advocate is someone who, during the course of an evaluation session, assumed an assigned role of promoting one particular attribute as being most important for health of collaboration. Because an advocate is assigned to every attribute, the positive aspects of the entire attribute will be brought out of group examination.

Table 2 Example of attributes in measuring health of collaboration

Perspectives	Attributes (some have been adapted from Lewis, 1990; Mohr and Spekman, 1994; Monczka et al, 1998)	State of collaboration				
		Very Weak	Weak	Mode rate	Strong	Very strong
		1	2	3	4	5
Commitment The level of commitment between partner Organisations	• Demonstrated performance is consistent /exceeds with mutual expectations. • Work is of acceptable / exceeds mutual target of quality • Work is of acceptable / exceeds mutual target of quantity • Satisfies partners' requirements, and meets /exceeds mutual expectations.					
Coordination The level of coordination between partner Organisations	Proactively works with partners to systemically resolve issues When taking regulatory actions, ensures that the partners fully understands the rationale and specific areas of non-compliance					
Trust The level of trust between partner organisations	Provides partners with data and information without doubt Let partners doing their task independently					
Communication The level of communication between partner organisations	Provides clear information that addresses the content and status of the products/ services Uses effective interpersonal skill in working with others. Objectively listens to the suggestions and comments of others. Demonstrates attention to and understands the concerns of others.					
Conflict resolution The level of problems discussions openly and manages conflicts constructively so that work is not adversely impacted.	Provide assistance to partners that lead to solutions. Facilitates resolution of diverse viewpoints. Anticipates conflicts and acts to resolve them. Practices conflict resolution. Looks for innovative ways to resolve conflicts. Proactively seeks resolutions that result in win-win situations.					

Measuring the outcomes of the Collaborative Network

Earlier works on the measurement for inter-organisational relationships namely alliance, mostly focuses on performance measures. Some works desire qualitative measures, for example satisfaction (Mjoen and Tallman, 1997), and others on quantitative measure, such as profit, revenues and cost (Mohr and Spekman, 1994; Contractor and Lorange, 1998). However, due to the multifaceted objectives, it is difficult to measure inter-organisational collaboration performance in a single criterion for instance with financial outcomes only (Gulati, 1995).

The outcome of the organisation usually associates with the performance. In a simple perspective, performance measurement is often linked to the efficiency and effectiveness of an organisation to satisfy its customers (Neely, 1999). Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm's resources are utilised when providing a given level of customer satisfaction.

Several frameworks, models and ideas for developing and defining performance measures for various business areas and processes have been conducted but most of those work related to a single company point of view (Bititci et al., 2003) and less in a network point of view. Logically, collaborative network is one "virtual" organisation, although it is formed from several organisations. Therefore, in general all performance measurement systems for an individual company can be applied to collaborative network organisation with some modification, including balance scorecard methodology. Through balance scorecard methodology, collaborative networks can measure their financial and non-financial values for customers, employees and shareholders. Table 3, shows some examples of these values.

Table 3 Example of value attributes for collaborative networks

Stakeholders that receive values	Value attribute	Measure	Weight
Shareholders	Profitability	Rate of return, Net profit margin	
	Asset growth	Percentage growth per-month	
	Company' image	Growth of image and reputation for external customers	
Customer	Service performance	Delivery speed, delivery reliability, percentage of on time delivery, delivery reliability	
	Product performance	Number of innovation product, numbers of new products, product reliability	
	Cost of products	Cheaper products compare to others	
	Customer relationship	Number of repeated order, number of new customers, number of claims	
Employees	Employee capabilities	Numbers of employees training hours	
	Motivation	Number of absent	
	Employee satisfaction	Numbers of employee turnover, numbers of fringe benefits for employees, percentage of salaries increased	

In order to evaluate participants' benefits in joining collaborative networks, output measurement before and after collaboration should be obtained. Logically, it is beneficial for a company if its output after collaborating is greater than output before collaborating. Let us take that TIO is output without collaboration and TNO is output with collaboration. A successful collaboration occurs if: TNO > TIO. Due to the enormous numbers of values that should be considered when measuring output, we propose a mathematical model as shown in Exhibit 1.

Exhibit 1 Mathematical model

For illustration, two companies A and B collaborate together. Mathematically, integrated value for both companies before joining collaboration:

$$TIOa = \sum_{p=1}^{m} (Wp \,.IVp) \qquad \ldots (1)$$

$$TIOb = \sum_{q=1}^{n} (Wq \,.IVq) \qquad \ldots (2)$$

Total initial values before collaborating is

$$TO1 = TIOa + TIOb \qquad \ldots (3)$$

After collaborating, new integrated value for both companies :

$$TNOa = \sum_{p=1}^{m} (Wp \,.NVp) \qquad \ldots (4)$$

$$TNOb = \sum_{q=1}^{n} (Wq \,.NVq) \qquad \ldots (5)$$

And total new value after collaborating is:

$$TO2 = TNOa + TNOb \qquad \ldots (6)$$

Where:

IVp = Initial value for attribute p
IVq = Initial value for attribute q
Wp = weighted of value attribute p
Wq = weighted of value attribute q
p = value attribute to company A
q = value attribute to company B
Possibly *p* equals *q* or *p* not equals *q*
m = number of value attribute for company A
n = number of value attribute for company B
Possibly *m* equals *n* or *m* not equals *n*
TIOa = Total initial output for company A before joining collaboration
TIOb = Total initial output for company B before joining collaboration
TO1 = Total initial output of companies A and B before collaborating
TNOa = Total new output for company A after joining collaboration
TNOb = Total new output for company B after joining collaboration
TO2 = Total new output of companies A and B after collaborating
NVp = New value for attribute p
NVq = New value for attribute q

There are thirteen possibilities can occur from this collaboration, however only one possibility that create value for both companies, that TO2 > TO1 and TNOa > TIOa and TNOb > TIOb

The rest possibilities probably make gain for one company only or even no one have gain.

CASE STUDY

In order to demonstrate how this model has been applied, we present one of the case studies conducted in the R & D sector. This is collaboration between a well-known Scottish based company in technology (H) and (S). They have collaborated for more than a year. They collaborate to develop an oil level controller of compressor by sharing resources and risks. There are three people employed from both side for this collaboration. Company H is a global provider of engineered products. The company's aim is to exceed customer expectations by applying innovation and technology to increase the value they add to their businesses. This collaboration is one of the commitments of company H to fulfil its vision. The vision of the company H is committed to partnering with its customers, suppliers and fellow employees to design and deliver world-class products and services.

In order to fulfil customers' requirement, both companies have to choose the right people who will work together to develop the innovative product. The right people should have technological skills in refrigeration system and optical system. Currently, three people are employed from each side of this collaboration. Company S is one of the suppliers to the company H. Both companies have strengths in different areas, but at the same time they also have few similar resources, which should be synergised in order to achieve the company's objectives.

The first step to measure contribution is factors identification. All selected factors and their description are summarised in Table 4. These factors are believed have contributed to the value creation in this collaboration. In order to quantify contribution of each: value generator, factor and partner in this collaborative network, pair-wise comparison is applied by managing director. An example of pair-wise comparison is shown in Table 5. The Consistency Index (CI) is checked for each set of judgments of pair-wise comparisons. When the CI is zero we have complete consistency; when it is greater than zero there is some inconsistency. The larger the value of the CI, the more inconsistent the judgments. If it is 0.10 or less the inconsistency is generally considered tolerable (Saaty, 1980). In this case study, CI for all judgments are under 0.10.

We can learn from this step that partners can use model to identify factors and then apply pair-wise comparisons as in AHP easily. The model has also provides partners the same chance to contribute idea or resources. After following all steps to measure contribution, all weights of factors are summarized in Table 6. Then Figure 4 shows both companies' contribution for each factor. The contribution of each factor shows the level of importance of each factor. Possibly the more important factor needs to be treated differently. We can also learn from the processes of measuring partners' contribution that partners can use model to make assessment objectively, partners can assess their partners and partners can make self assessment as well.

The contribution of each factor combined with the weight of each factor led to the total contribution of each company within collaborative enterprise. In this case study, total contribution of company H is 67.3 % and S is 32.7 %. Even though management intuitively thought that probably contribution should have been about 80% for H and 20% for S, in general, participants found the model and results interesting.

This case study has also proven that contribution of each factor in creating more value for the collaborative enterprise can be measured through pair-wise comparisons of AHP. In terms of the healthy relationships, partners found that overall, this collaboration is strong enough. This meant the healthy relationships have affected the output significantly. Therefore both companies received adequate reward for their work in terms of the returns from sales. However, partners have difficulties to explore all kinds of value that they received during the collaboration project.

Even though decision maker can apply model easily, but measuring partners' contribution, measuring the health of collaboration and measuring outcome are not an easy process. It needs a strong commitment to make decision objectively, especially when determining priority with pair-wise comparison and when making assessment with data grid.

Table 4 Value generators and factors of case study

Value Generator	Factors	Measurement indicators	Description
Financial asset	Cash	Total cash spent for developing new product including cost for R & D and market test.	All costs distribute equally
Physical assets	Building and tools	Availability rate	Available to be used for new product development in a particular time.
Human capital	Skills	Numbers of product failures, numbers of waste materials	That have affect in develop particular product
	Experiences	Average numbers of years in related products	That have affect in increasing quality of products
	Education	Numbers of graduated employees,	Those that have an affect in quality of products.
	Knowledge	Numbers of proposals/suggestions from team members to increases quality, product performances, etc.	Those that have an affect in develop better products.
	Competencies	Level of understanding to works with: a variety of technologies, complex interrelationships, acquires and evaluates information.	Surveys through management/ employers of team members and partners.
	Time spent	Average hours spent by team members to develop products	This is used to improve new product.
	Productivity	Numbers of new ideas/time spent	That have an affect in increasing collaboration output
	Commitment	Numbers of time team members deny / absent from appointment.	Those have affect in producing and developing new products to the market.
Organisational capital	Brand name	Numbers of customers buying a product due to the "brand" of partner/producer.	Customers when buying product consider this factor. Surveys through customers
	Product performances	Level of customers satisfaction index related to product	Customers when buying a product consider this factor Surveys through customers
	Organisation culture	Percentage of employees understanding and applying vision, mission and collaborative enterprise's and company's values	This has an affect in motivating employees to do their best. Surveys through team members and management of parent's company.
	Innovation technology	Numbers of new innovative technology products/designs	Those have been applied collaboratively.
Relational capital	Maintain market	Numbers of repetitive order from the existing customers, Number of customers recommend our product to new customers	This is used to maintain and improve market share. Surveys through customers
	Service performance	Customer satisfaction index related to the service e.g. after sales service performance etc.	This is used to maintain and improve market share. Surveys through customers

Table 5 Pair-wise comparison amongst Value Generators

Value generator	FA	HC	OC	PA	RC
Financial Assets (FA)		1/5	1/3	¼	1/3
Human Capital (HC)			3	4	3
Organisational Capital (OC)				½	2
Physical Assets (PA)					1
Relational Capital (RC)					

Table 6 Factors and weights

Value Generator	Factor	Weight
Financial Asset	Working capital	0.056
Human capital	Skills	0.105
	Experiences	0.045
	Education	0.020
	Knowledge	0.107
	Competencies	0.072
	Time spent	0.043
	Productivity	0.017
	Commitment	0.047
Organisational capital	Brand name	0.013
	Product performance	0.051
	Organisational cultures	0.009
	Innovative technology	0.065
	Intellectual property	0.025
Physical assets	Building and tools	0.188
Relational capital	Maintain market	0.0.28
	Service performance	0.111

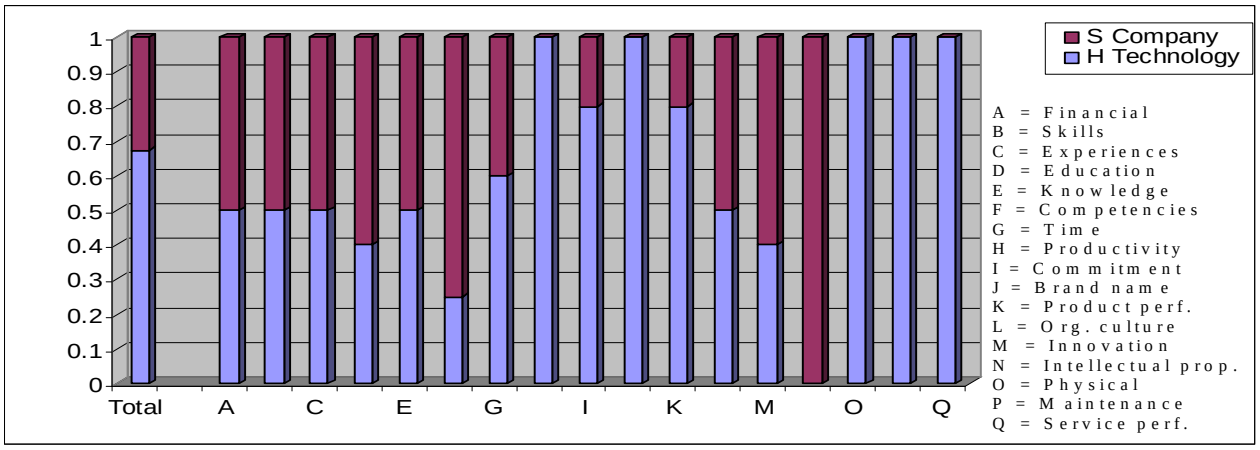

Figure 4 Contribution of each factor

DISCUSSION AND CONCLUSION

The paper has identified different types of collaborative networks and categorised each one of the existing collaborative networks, i.e. supply chains, extended enterprises, virtual

enterprises and clusters. The categorisation is according to the “things” that are shared by participants, such as data, information, resources, systems, risks and benefits. The categorisation is led by key characteristics of each type of collaborative network. Table 7 represents a first attempt at identifying these characteristics.

Table 7 Sharing tendencies in the collaborative network

Type of collaborative enterprises		**Supply chains**	**Extended Enterprise**	**Virtual enterprise**	**Cluster**
A tendency to	Shared data and information	high	high	high	high
	Shared resources	low	high	high	high
	Shared systems	moderate	high	high	low
	Shared risk	moderate	high	high	moderate
	Shared benefits	low	moderate	high	low

Implied by the previous section, it is clear that the focus of a collaborative network is to encourage close relationship and create more value among participants by contributing particular resources. Therefore, to collaborate here means to work together in a win-win situation and create a healthy relationship, share resources and enhance each other’s value for mutual benefits.

It can be concluded that an organization should always assess the particular advantages of collaborative networks. If a company decides to join a collaborative network, it should be careful in evaluating its partners and to think about interaction amongst partners and the contributions of each partner. However, from this limited discussion it is clear that providing metrics is not a solution for all problems in collaborative networks. There are various reasons for failure, and lack of the appropriate metric is only one of those reasons.

This paper presents a conceptual metric from three perspectives, input - process - output. However, to state that one particular collaborative network will sustain or not, measurement should be made in all perspectives. Measurement in one perspective can only be used to evaluate partners’ activities in that perspective. For example, each partner to evaluate involvement of its partner resources could use the results of measuring contribution;

however, it cannot be used to evaluate the closeness of the relationship and outcome for every partner.

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