Applying systems thinking to solving the problem of vertically integrating Taiwan's small and medium sized enterprises

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Abstract – Taiwan is a country whose industry mainly consists of Small and Medium enterprises (SME Administration, 2007). Many of these SMEs manufacture mechanical and electronic components and subassemblies. There is now a desire to move up the value chain and perform systems integration as well as the manufacture of the subassemblies of the system. However, the knowledge and skills required for systems integration are different to those needed for component and subassembly manufacture. This paper applies systems thinking to conceptualize a way in which Taiwan's SMEs could vertically integrate[1] with minimal disruption to the working of individual SMEs by creating an eastern virtual equivalent of a western large corporate systems integration house with a slight modification to the Taiwanese SME's current way of teaming[2].

Keywords: Systems thinking, small and medium enterprises, vertical integration, active brainstorming, early phase systems engineering

Introduction

Taiwan's Small and Medium Enterprises (SME) produce various products and services, many of them hi-tech items that are incorporated in the increasingly complex technical systems that underpin society. The SMEs are facing increasing local and global competition and have a desire to vertically integrate. Since vertically integrated organizations need knowledge, skills and competencies that SMEs may not have, the problem is to figure out a way of vertically integrating these SMEs and providing any missing knowledge and competencies. The solution also has to conceptualize both a way of providing vertical integration and of producing quality products and services.

This paper briefly summarises active brainstorming and then applies the technique to conceptualising a whole functional and purposeful solution to the problem of vertically

[1] Vertical integration is defined as the process in which several steps in the production and/or distribution of a product or service are controlled by a single company or entity, in order to increase that company's or entity's power in the marketplace (Investorworlds.com, 2008).

[2] Parts of this study are based on research which led to the award of a Doctor of Science in Engineering Management at the George Washington University, Washington DC.

integrating Taiwan's SMEs with minimal disruption to the working of individual SMEs. The paper develops a hypothesis for a conceptual solution and ends with recommendations for a pilot scheme to test the feasibility of the conceptual solution.

Active Brainstorming

Active brainstorming (Kasser, 2009) is a proactive method of producing ideas relating to the problem or issue in a systemic and systematic manner. It does this in a systematic manner by examining the issue from each of nine systems thinking perspectives (STP) (Kasser and Mackley, 2008) and triggering ideas systemically and systematically by asking questions beginning with or incorporating the words "who", "what", "where", "when", "why" and "how" (Kipling, 1912). Active brainstorming uses Table 1 as a template to trigger ideas from each STP as follows. When the session begins, there will be a natural tendency to generate spontaneous ideas in an unstructured manner, particularly in a session containing newcomers to the technique. Once the initial flow of ideas stops, the facilitator starts the true active brainstorming process using the active brainstorming template at the operational perspective row of Table 1 and poses questions from column 1 beginning with or related to the word "who". When the ideas stop flowing, the facilitator moves on to the next question in the row. At the end of the flow of ideas from the last question in a row, the facilitator moves down to the first question in the next row. Expect a question in posed one area of Table 1 to sometimes generate ideas that pertain to other areas. If no ideas come forth immediately since not all areas are pertinent to every problem, the facilitator should skip to the next question.

Table 1 Active Brainstorming Idea Triggering Worksheet

STP Matrix	1	2	3	4	5	6
	Who?	What?	Where?	When?	Why?	How?
Operational						
Functional						
Big picture						
Structural						
Generic						
Continuum						
Temporal						
Quantitative						
Scientific						

Active Brainstorming the problem

This part of paper applies active brainstorming to the problem of vertical integration documenting some of the questions and responses as follows:

Big Picture perspective

- *<u>What</u> is the total system?* The production company and its suppliers. As such, mapping the Value Chain into the system crosses company boundaries. For example, consider the Value Chain drawn in Figure 1 across six SMEs. The functions are represented by letters and are grouped into the SME organizations (i.e. functions A and B are performed in one SME, functions J and O in a second, etc). Value is added as the products move along the chain from supplier to buyer. The initial functions produce components, the next set integrates those components into subsystems and the highest level (furthest to the right)

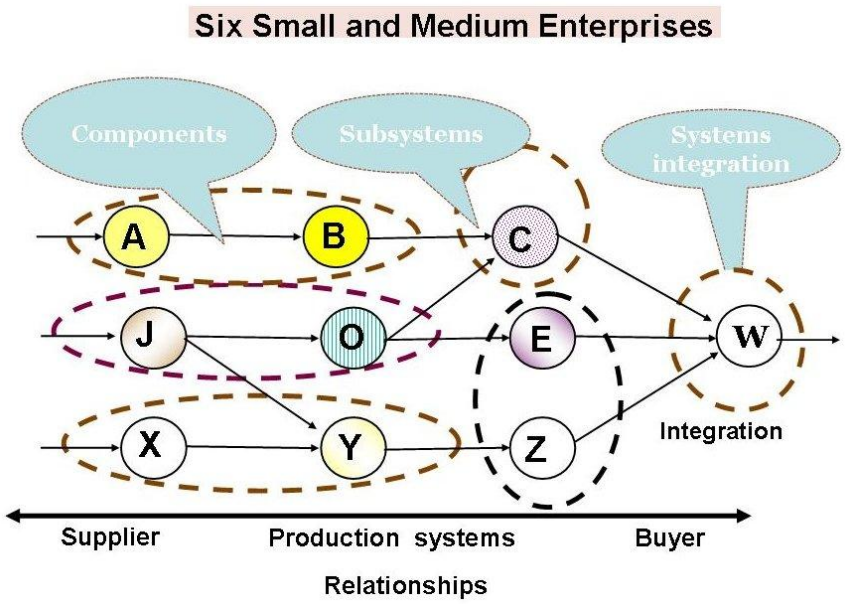

Figure 1 The Value chain

integrates the subsystems into systems.

- *How many subsystems are there in a production company?* Two subsystems, production and support.
- *What do SMEs do?* They produce components and provide services.
- *What is driving the need for vertical integration?* The desire to increase revenue share of total system production by performing systems integration.

Functional perspective

- *What functions do SMEs perform?* Production, sales, service, marketing, research, etc.

Generic perspective

- *Who else performs the same functions?* Large companies.
- *What is the difference between large companies and SMEs?* The resources of SMEs are more limited. They lack the deep pockets and "spare" personnel of the large companies.
- *What is happening in elsewhere, for example in the USA?* Many SMEs do the same kind of systems engineering and technical assistance (SETA), software and hardware engineering, operations support activities as do the large corporate contractors (Kasser, 1997a).
- *What is happening in Taiwan?* A number of things. First, the Corporate Synergy Development Center (CSDC), a non-profit organization established in 1984, by the Industry Development Bureau (IDB) of Ministry of Economic Affairs (MOEA) provides technical services for SMEs including BPI, CM, e-Service, TPS, TPM, TQM, etc. Second, SMEs in Taiwan already seem to be working together in consortia as shown by the following examples:

    - Bicycle Industry - A-Team, started in 2003, led by Giant and Merida with more than 20 SMEs participating, formed a cluster in Taichung, Center part of Taiwan (Liu and Brookfield, 2007).
    - Tool Machine Industry - Another great example of the Taichung area industry cluster. The current success of Taiwan's machine tool industry is due to the competitive advantages achieved through flexibility, delivery, and price by the

user-producer interaction of the factory satellite network system in the industry cluster in the Taichung area. The success of the diffusion of technology from bridging institutions to industry has also been an important factor (Ching-Chiang Yeh and Pao-Long Chang, 2003).

- M- Team established for machine tool industry in Sept. 2007 under the IDB and The Corporate Synergy Development Center(CSDC) assistance, (Liu, 2008).
- Fastener Industry - S-Team established, FPD Industry, Hand-Tool Industry, are examples of SMEs working together.

- *What lessons can be learned from the concept of alliances or teams of organizations?* Applicable lessons learned from the USA include:
  - Writing about organization dynamics (Beckhard, 1969) stated that there is a considerable payoff if a new team can take a short period of time at the beginning of its life to examine collaboratively how it is going to work together, what its methods, procedures, and work relationships will be, and what the priority concerns of its members are. Then the team works more effectively, has fewer interpersonal problems, is more productive, and is more meaningful to its members.
  - Writing about alliances, (Drucker, 1993), pp 289-291) stated the following six issues need to be resolved for the alliance before an opportunity arises: All parties must:
    1. Define their own objectives.
    2. Agree on the objectives of the alliance.
    3. Agree on how the alliance should be run.
    4. Agree on who should manage the alliance.
    5. Define the formal organizational relationship between the alliance and its own organization, including the responsibility and accountability.
    6. Agree on how to resolve disagreements.

Temporal perspective

- *Where did systems development and integration begin?* It began in SMEs since the large corporations evolved from SMEs. One prominent example is the way Henry Ford vertically integrated the Ford Motor Company to ensure quality, timeliness of delivery and reliability of parts (subsystems) (Ford and Crowther, 1922). However, as time went by, vertical integration tended to produce poor quality and high inventory stocks (sometimes of poor quality parts).
- *How has consistent quality been guaranteed by a single entity in the past?* The ISO 9000 standards were developed to ensure that consistent quality of the process and products of parts suppliers would be verified by a single impartial entity.
- *How is modern supply chain economics addressing the issues of quality and timelines of delivery of components?* In the form of consortia of companies working together rather than using Ford's vertically integrated single company approach.
- *What about inventory costs and timeliness of delivery?* Outsourcing of parts manufacturing by large companies to SMEs is common and the Just-In-Time (JIT) manufacturing/delivery concept tends to overcome issues with excessive costs of inventory and tends to ensure timeliness of delivery.

Structural perspective

- *How can organizational structure be improved?* Organizations evolved into the current hierarchical format due to issues related to "span of control". However, flattening of the hierarchy can now be achieved by:

- Management by exception (reference to be supplied)
- Information technology (Rodgers, et al., 1993).

Continuum perspective

- *What are some alternative organisational structures?* The traditional systems engineering approach to organizational design allocates functions to physical elements or departments within the same organization. However, one can visualize an alternate arrangement with separate functional and organizational boundaries so that the functions can be performed by different SMEs working together as a consortium (Kasser, 1997a). This concept is similar to a temporary project organisation within a large corporation and in this context seems to be an application of the Reengineering concept (Hammer and Champy, 1993). Thus, back to the big picture perspective, the structure of a large corporation and the structure of a consortium of SMEs performing the same functions looks the same from the outside as shown in Figure 1. The difference as discussed below is that to ensure the quality of the final system/product, all the functions except Enterprise Management are performed by more than one SME in an internal (to the consortium) multiple award task ordered (MATO) contracting environment.

Scientific perspective

- *What hypotheses could be stated for conceptualizing a way in which Taiwan's SMEs could vertically integrate with minimal disruption to the working of individual SMEs?*
    1. A consortium of SMEs can form a virtual large company.
    2. Systems engineering can be used to design and build the consortium.
    3. Quality can be ensured by limited competition in a cooperative multiple award task ordered (MATO) contracting environment.
    4. The SME consortium MATO structure offers greater benefits to the stakeholders than those available from large corporations.

The hypotheses

Consider each hypothesis in turn.

1. A consortium of SMEs can form a virtual large company. The virtual large company is process-based (Hammer and Champy, 1993) page 28), uses a systems approach and considers an organization as a four dimensional system (product, process, people and time) (Kasser, 1995). As such, systems engineering methodologies can be used to view, decompose and optimize the organization.

The generic perspective has shown that the hypothesis has been supported by the formation of consortia in the Bicycle, Machine Tool, and Fastener Industries in Taiwan as discussed above.

2. Systems engineering can be used to design and build the consortium. Consider the solution consortium from various STPs. The big picture perspective would be used to determine scope and range of products to be produced. The operational perspective would identify the Value Chain in as a process flow ensuring a product transfer at each functional boundary (Kasser, 1997b). In creating this consortium or designing the production system, the functional perspective of the value chain would be created first, and then the SMEs are mapped on to the value chain in the manner of Figure 2 to produce the structural perspective. In this case, the steps are:

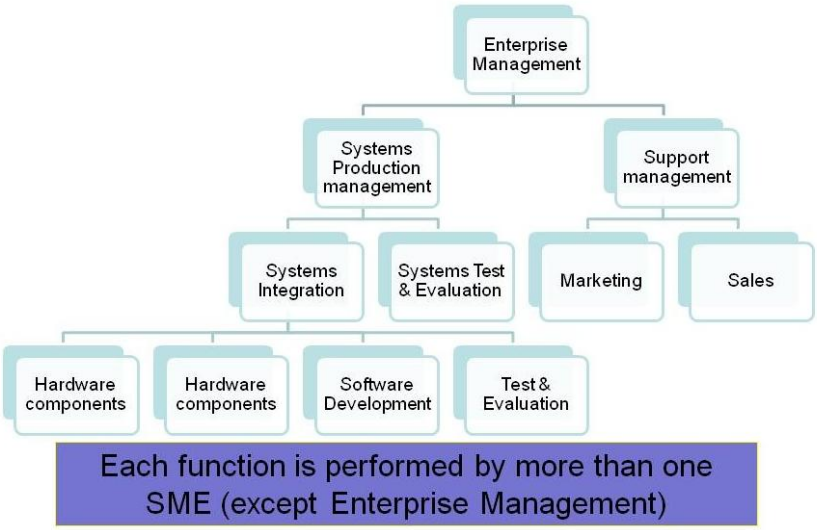

Figure 2 Structure of Consortium

1. Identify the functions performed by the production system to produce or purchase the components, subsystems and perform systems integration.
2. Except for the Enterprise Management function, identify several SMEs who can perform each function. Thus each SME can continue to perform its core competency.
3. Note the instances where a function cannot be allocated to an SME. This is an opportunity to create a new SME or for an existing SME to grow.
4. Create the missing functions from the existing members of the consortia or invite additional SMEs to join. Distance in itself is not a factor.

3. Ensuring the quality. Quality can be ensured by always transferring products at SME boundaries. These products must be tangible items manufactured according to a specification. Quality will be assured in the contract accordance with (Crosby, 1979)'s assertion that "quality is conformance to specifications". The products may be systems engineering process-products in the form of documents or electronic databases, or hardware and software components and assemblies. The production work is organized using a multi-contractor technical task management methodology which:

- Was evaluated as "very good" by a United States Air Force Source Selection Board when incorporated in a proposal (Kasser, 1997a).
- Separates the work into several tasks and produces written task work plans (TWPs). Each TWP is a written contract between the consortium members and may be used to:
    - Optimize management across the organizational boundaries.
    - Enforce quality into the contractual structure.
- Emphasizes teamwork and customer involvement.
- Is tailored to the formality necessary for specific tasks of different degrees of complexity, ranging from single person tasks, to tasks requiring a large team of employees with interdisciplinary skills.
- Is loosely based on a methodology used by a large contractor for eight calendar years in a task ordered environment at NASA GSFC (Kasser, 2007).
- Improves on the basic methodology by adding the element of quality using the anticipatory testing paradigm (Kasser, 1995). The improvement:
    - Ensures work is performed in a cost-effective manner.
    - Maps very well into managing tasks performed in geographically distributed

locations by different organizations such as in this project.
    - Intrinsically incorporates task management into program management.
    - Builds the quality into the task.
    - Reduces the cost of doing work.
- Allows the needed staffing levels and skill mix to undergo the gradual change required to perform the planned work in an optimal manner.
- Establishes baselines for the planning activity.
- Monitors task and contract performance relative to the baseline plan.
- Develops measurements of the effectiveness of performing the work.
- Incorporates control functions that effectively deal with deviations from the baseline plan in a timely manner.

The Enterprise Management Company is the holding company and provides bridging financing to the members of the consortium. When the Enterprise Management Company sets up the consortium, it arranges for a pool of teaming SMEs who agree to compete for tasks on an agreed set of criteria in a multiple-award-task-order scenario that is transparent to the customer. The single point interface between the Enterprise Management Company and the customer remains exactly the same as in the conventional approach large corporation. Work orders are transmitted from the customer to the Enterprise Management Company as in the conventional approach. The difference is in what happens to the work orders in the Enterprise Management Company.

The Enterprise Management Company is a "task broker" planning, organizing, directing and measuring the work. In this scenario, the Enterprise Management Company has three functions, namely:

- Breaking the work down into tasks using process architecting techniques.
- Competing each task among the pool of qualified SMEs in the consortium.
- Locating and qualifying additional potential consortium members. This potential inflow of new talent will tend to inhibit the consortium members from becoming complacent in their activities and keep the costs down.

4. The SME consortium MATO structure offers greater benefits to the stakeholders than those available from large corporations.

This concept of a federation of SMEs performing systems integration appears to have many advantages to the SMEs, the government and the customers with few disadvantages. These advantages and the few disadvantages are summarized as follows:

Benefits to SMEs include:

- No need to change core competency to join consortium.
- Long term relationships with other members of the consortium help to develop future opportunities.
- Consortium work can be scheduled in advance so the workload is known.
- Allows for SME to work outside consortium to make use of extra capacity.
- All SME need not be local, for example suppliers can be overseas.
- The final Integrator in overseas contract can be a local (overseas) company. This concept has been used successfully in several industries in which components manufactured in one country have been shipped to another country and assembled/integrated in the second country by a “local” manufacturer.
- Good learning and political opportunity. Teaming with an established systems integration house in an overseas country will be a good way to learn the process and create opportunities for expansion of business.

Benefits to Government include:

- No need to give away future tax revenue to lure large (overseas) companies.
- Revenues; tax is collected from consortium (local SMEs).
- Knowledge, skills and competencies remain local.
- Funds support local (mainly) SMEs.

Benefits to customers include:

- Contractual structure ensures:
    - Lower probability of fraud, waste and abuse and earlier visibility of deficiencies in the system development lifecycle because the Enterprise Management Company will be aware of deficiencies at the first contractual handover point between SMEs in the value chain.
    - Better quality than from single large company produced system since it is in the (internal consortiums contracts) contract and reputation of SME.
- Lower cost due to lower SME overheads
- Increased innovation in products because SMEs are more innovative than large companies.
- Probable increase in reliability due to lack of service network which provides incentive for supplier to increase reliability.

The disadvantages are few, and mainly reflect the change in the manner of doing work. For example:

- System integration by a consortium of SMEs is a new concept, so it will need to provide incentives to overcome resistance to change
- The SMEs may have to share cost information with consortium partners who might be future competitors. However, this will depend on internal consortium financial agreements and will be different in a profit sharing or fixed price contractual environment.
- Formation and ramp up will take time and probably will need government help. A pilot project to use as an example in marketing the capability to all potential stakeholders will probably be needed.

Recommendations

This has been an example of an early phase systems engineering feasibility study addressing a need in Taiwan. The study findings are that the concept seems to be workable and win-win. In fact Taiwanese SMEs seem to be doing something similar but have not applied it to systems integration. The logical next step up the integration path would be to form such a consortium. As a pilot project, a start could be made adapting an existing consortium such as:

- The A-Team, M-Team, S-Team, Hand-Tool Industry Alliance, FPD Industry Alliance
- The newly established Digital Innovative Service Industry Alliance (DISIA) by IDB of MOEA.
- The innovated new Chinese life style service industry for crossing the Taiwan Strait in a single day.

Many details will need to be developed. These details requiring further study include:

- Types of products/systems
- Contractual structure
- Missing functions

- Developing prototype
- Leveraging on existing product lines
- Potential partners

The recommendation is to take the study to the next step and start with a Strength – Weakness – Opportunity – Threat (SWOT) analysis for a number of specific opportunities.

Summary

SMEs in Taiwan are facing the need to vertically integrate from component manufacturers to systems integrators. This paper has documented the application of active brainstorming in an example of early phase systems engineering and examined one way in which SMEs in Taiwan could form a consortium to vertically integrate in a win-win manner.

Conclusion

The concept spears to be feasible and win-win and should be examined in more detail with the goal of initiating a pilot project.

Authors

Joseph Kasser has been a practicing systems engineer for nearly 40 years and an academic for about 10 years. He is an INCOSE Fellow, the author of "A Framework for Understanding Systems Engineering" and "Applying Total Quality Management to Systems Engineering" and many INCOSE symposia papers. He is a recipient of NASA's Manned Space Flight Awareness Award (Silver Snoopy) for quality and technical excellence for performing and directing systems engineering and other awards. He holds a Doctor of Science in Engineering Management from The George Washington University, is a Certified Manager and holds a Certified Membership of the Association for Learning Technology. He has also served as the initial president of INCOSE Australia and Region VI Representative to the INCOSE Member Board. He gave up his positions as a Deputy Director and DSTO Associate Research Professor at the Systems Engineering and Evaluation Centre at the University of South Australia in early 2007 to move to the UK to develop the world's first immersion course in systems engineering as a Leverhulme Visiting Professor at Cranfield University. He is currently a principal at the Right Requirement Ltd. in the UK and a Visiting Associate Professor at the National University of Singapore.

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