CHAPTER 2

LITERATURE REVIEWS

Extensive literature survey has been carried out to ascertain the findings of earlier studies in industry-university collaboration. This chapter is divided into nine sections, namely the objective of the partnership, benefits from industry-university interactions, motivation of industry and university regarding technology transfer, demand pull or technology push for building partnerships, types of industry-university interactions, structure of industry demand side and university supply side, evolution of technology transfer, obstacles of relationships, and critical success factor in building the relationships.

2.1 Objective of the Relationship/Partnership

The advent of global competition in the last decade or so has forced universities and industries to re-examine their roles in respect of society an each other. In order to succeed in this fast-moving competitive world, industry cannot possibly be resident in any one company. Moreover, it would be tantamount to dereliction of duty for an R&D organisation to insist on laving all the resources for modern technology development under its direct control. Cost is another reason. It is a fact that others can often do your research cheaper, better and lower risk than you can. University is a source to help the industry. Universities are not just powerhouse of new knowledge and inventions, but also, state organs for manpower training and wealth creation to spur and sustain economic growth.

Industry and university have always had symbiotic motives and objectives for collaborating. University is a source for industry to keep up on new development, renew their idea-well and recruit new employees. While industry is a natural source of funding for university's lecture and research program, a means for university to maintain its real world relevance, and a source for faculty consulting and student employment (Sounder, 1993)

The role of universities regarding the needs of industries can be summarised as to maintain a window to new technology, to educate future scientific employees and to compensate for lagging federal support in R&D, as well as responding to the needs of national development (Shenhar, 1993). The effectiveness of university-industry relationship has a direct impact on the economic development and the problem of competition (Gee, 1993). Thus, universities should be considered as a partner of industry to discuss needs and try to solve problems of industrial companies. Through rendering this service, universities can acquire additional funds to survive, develop new buildings, laboratories and for doing research etc.

The possibilities for interaction between industry and university are relatively wide and probably no common pattern can be found (Shenhar, 1993). The mutual cooperation is not established easily, normally there is a lack of communication and nobody wants to come first. Therefore, both engineers and researchers/lecturers do not know each other well enough and whom they should contact to discuss these problems/suggestions. In section 2.2, the potential benefits from industry-university collaboration will be discussed.

2.2 Potential Benefits from Industry-University Interactions

Several academic and industry researchers and managers have written on the topic of what can be gained from university-industry interaction. Geiseler, et al. (1989) summarises various benefits that may accrue to industry and universities as the result of the interaction in following table.

Table 2.1: Potential Benefits from Industry-University Interactions; Source: Geiseler, et al. (1989)

1. Benefits to industry
- Window to technological state-of-art
- Systematic review of faculty research results
- Specific skills and knowledge provided by faculty consultants.
- Training of industrial scientific/technical personnel.
- Participation of faculty members in industrial conferences.
- Source of highly skilled scientific/technical employees
- Solving specific problems for industrial projects
- Join effort, start-up businesses, economic payoffs
- Access to university facilities
- Cost savings
- New markets
- Manufacturing and lead time reduction
2. Benefits to university
- Practical updating of faculty and students
- Funding for research as well as capital investments
- Development of university curricula
- Industrial membership on university advisory committees
- Access to industrial facilities and equipment
- Ability to government funds for applied research with industry
- Join effort, start-up businesses, economics payoffs
- Cost savings

In addition, several main reasons, which are claimed to motivate the industry to increase industry-university cooperation, have been provided by Altan (1990) and Peters and Fusfeld (1982). They are: (1) access to manpower, including well-trained graduates and knowledgeable faculty; (2) access to basic and applied research results from which new products and processes will evolve; (3) solutions to specific problems or professional expertise, not usually found in an individual firm; (4) access to university facilities, not available in the company; (5) assistance in continuing education and training; (6) obtaining prestige or enhancing the company's image; and (7) being good local citizens or fostering good community relations.

On the other hand, the reasons for universities to seek cooperation with industry appear to be relatively simple. Peters and Fusfeld (1982) have identified several reasons for this interaction: (1) industry provides a new source of money for university; (2) industrial money involves less "red tape" than government money/ (3) industrially sponsored research provides student with exposure to real world research problems; (4) industrially sponsored research provides university researchers a chance to work on an intellectually challenging research programs; (5) some government funds are available for applied research, base upon a joint effort between industry and university.

Similarly, Barber (1985) has identified three factors, which appear to have been most instrumental in stimulating university interest in enhanced industry-university relations. These are: (1) reduced federal support of research; (2) deteriorating university research equipment; and (3) economic benefits to university.

2.3 Motivation of Industry and University Regarding Technology Transfer

The motivation of industry as the transferee is based on the need of solving its problems regarding technology development or just modification of the product and improving the quality of equipment/machines, improve technological capabilities, and gain more competitive advantages.

The motivation of university as the transferor of technology mostly emerges from the need of funds for research and development. The other motivations are building a good image, getting more involved in national economic development and be able to compensate the researchers better for their work.

2.4 Relation Between Component of Technology and Linking Mechanism of Technology Transfer

Technology really comprises four interrelated components, which take the following forms,: (Ramanathan, 1994a)

- Object-embodies technology, which can be called Technoware. Technoware consists of tools, equipment, machines, vehicles, physical facilities, etc.
- Person-embodied technology, which can be called Humanware. Humanware refers to experiences, skills, knowledge, wisdom, creativity, etc.
- Document-embodied technology, which can be called Inforware. Inforware includes all kinds of documentation pertaining to process specifications, procedures, theories, observations, etc.
- Institution-embodied technology, which can be called Orgaware. Orgaware is required to facilitate the effective integration of Technoware, Humanware, Inforware, and consists of management practices, linkages, etc.

The linking mechanism of technology transfer for every university service is described in Table 2.2 below.

Table 2.2: The Relation Between Components of Technology and Linking Mechanisms for Technology Transfer

Linking Mechanisms	Components of Technology that Flow from Universities
Licensing (prototype, design, etc.)	Technoware, Inforware
Technical Advice/ Consultancy	Humanware, Inforware
Using Library	Inforware
Joint Research	Technoware, Inforware, Humanware
Guest Lecture	Humanware, Inforware
Consortium	Technoware, Inforware, Humanware
Market Analysis	Inforware
Training	Inforware, Humanware
Laboratories Test	Inforware

2.5 Demand Pull or Technology Push for Building Partnerships

Demand-pull by the industry is more effective than technology push by the university. Industry, which usually monitor its shop floor, find some problems regarding the machines, the material, the formula, design, packaging, processing, etc. In so far as they know what their problems are, they often do not know how to solve them. So they bring them to the university. The university should have strong technology capabilities and research capability. Demand-pull and technology push should be together. Each partner's input is vital for success. Each plays a role in supplementing the other's strengths, minimising weaknesses and filling gaps necessary to accomplished objectives (Gee 1993). Figure 2.1 shows a model of partnerships with demand-pull initiative by university.

Industries increasingly have to consider improvement in their technology sophistication because of global competitiveness in the market. Universities, especially public universities, are strong in technology capabilities and research because of good facilities and active research work, also because of funding from government.

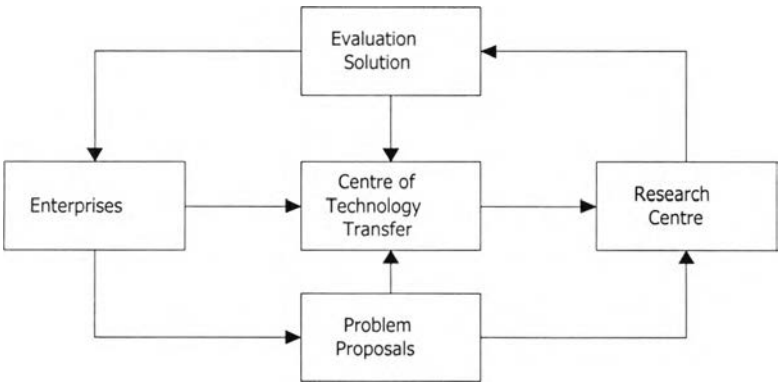

Figure 2.1: A Partnership Model with Demand Pull Initiative; Souce: Ambrosio (1995)

2.6 Types of Industry-University Interactions

Types of industry-university interactions arise from the following research by Geisler and Rubenstein (1989), Bohez and Tabucanon (1999), Tao (2000), Sounder (1993), and Bonaccorsi and Piccaluga (1994).

Geisler and Rubenstein (1989) addressed a description of types of university-industry arrangements and illustrative mechanisms associated with these arrangements as shown in Table 2.3.

Table 2.3 Types and Mechanisms of Industry-University Relations

Type of Arrangement	Modes of Interaction and Some Mechanisms
Industrial Extension Services	Information transfer and consulting.
	Workshops, classes
	Undirected corporate gifts to university fund
	Capital contributions to university departments, centres, laboratories
	Industry fellowships
Procurement of Services	By university from industry. Prototype development, fabrication, testing, on the job training for students
	By industry from university. Education and training of employees; contract research, consulting services
	Industrial associates. Industry pays fee to university to have access to total resources of the university
Cooperative Research	Joint research planning and execution
	Faculty and student participation
	Cooperative research projects: direct cooperation between university and industry on projects of mutual interest; usually basic, non-proprietary research. No money changes hands; each sector pays salaries of own scientists. May involve temporary transfers of personnel for conduct of research
	Cooperative research programs: industry support of portion of university research project; results of special interest to company; variable amount of actual interaction
	Research consortia: single university, multiple companies, basic and applied research on generic problems of special interest to entire industry; industry receive special reports, briefings, and access to facilities
Research Parks	Research cooperation on frontiers of science and technology
	Informal interactions
	Increased sharing of research facilities and participation in consulting, seminars, and continuing education
	Contractual arrangement—specific and detailed; both parties contribute substantially to the enterprise

Bohez and Tabucanon (1999) organised the models for university-industry partnership into five categories; no-model model, agency model, membership model, university-industry research-oriented parks and business-oriented parks. They describe the detail of each model as below:

- **No-Model Model.** No particular procedure or channel is applied when the university is contacted occasionally by industry or vice versa.
- **Agency Model.** There is an agent between university and industry as a one-stop shop or one-stop information.
- **Membership Model.** University and industry contact each other through an engineering/scientific club established by the university. Industries as the members pay the membership fee annually.
- **University-Industry Research-Oriented Parks.** A continuum of parks in increasing degree of interaction starts from Research Park, to Innovation Centre, to Science Park, to Technology Park, then to more Business-Oriented Parks like Business Incubators, Business Parks and Industrial Parks.

  Research Parks concentrate on basic and applied research and extend research only until the production of prototype. **Innovation Centres** are small developments which provide facilities to enable start-up and small business to develop idea, but which do not provide accommodation either for such business once they have grow. **Science Parks** are oriented toward research but also provide accommodation for both start-up and medium sized establishment, generally in a setting where small-scale manufacturing can take place. **Technology Parks** are suited to a wide range of activities, from research and development to high technology and light manufacturing activities to office and administrative functions and services.

  Business-Oriented Parks are in three forms. **Business incubators** are developed to help small businesses to start-up in the most favourable environment with minimum entry requirements in the form of direct capital investments. **Business parks** focus on the provision of good environment to office, light manufacturing and business support services. **Industrial parks** are oriented towards traditional production, service and distribution and are not well suited to a wide range of high technology activities.

Tao (2000) pointed out the industry-university partnership models (see Table 2.4).

Table 2.4: Industry-University Research Partnership Models; Source: Tao (2000)

Industry-University Research Partnership Models
I. Single Company-Multiple Universities
- Hoeschst Celanese with Rutgers University, North Carolina State University, University of North Carolina
- Air Products and Chemicals, Inc. with Imperial College, Pennsylvania State University, Georgia Institute of Technology
II. Multiple Company-Single University
- MIT Media Laboratory with Hewlett Packard, Phillips, Digital Equipment Corporation, and others
- Imperial College with Air Products and Chemicals, Inc., British Petroleum, Rhone Polene, Unilever, Fujitsu, Microelectronic and Computer Technology Corporation
III. Multiple Companies and Multiple Universities
- Pennsylvania Infrastructure Technology Alliance with Lehigh University and Carnegie Mellon University

Sounder (1993) proposed the lists of collaboration types which are divided into three categories (Table 2.5):

- Informal type;
- Semi formal type;
- Formal type.

Table 2.5: Types of Collaborations; Source: Sounder (1993)

Examples of Informal Types of Collaborations	Examples of Semi Formal Types of Collaborations	Examples of Formal Types of Collaborations
Student project	Equipment sharing	Industry adjunct professorships
Interest groups	Graduate fellowships	Cooperative educational programs
Study committees	Consulting agreements	Direct sponsorships
Ad-hoc forums	Field site arrangements	Sharing of intellectual property
Discussion groups	Industry committees	Joint R&D arrangement
Consultations between parties	Standards committees	Incubator facilities
Information sharing networks	Seminars and training courses	Technology licensing programs
	Industry sabbaticals	Industrial affiliates programs
	Release-time sabbaticals	Endowed research centres
	Reverse sabbaticals	Endowed chairs and professorships
	Gentle agreements	Cooperative instructional

Examples of Informal Types of Collaborations	Examples of Semi Formal Types of Collaborations	Examples of Formal Types of Collaborations
		programs
	Joint bidding agreements	Industrial fellowships
	Co-production agreements	University extension services
	Cooperative grants	Science park and centres
		Engineering research centres
		Science and technology centres
		Industry-university collaborative research centres (IURCs)

Bonaccorsi and Piccaluga (1994) on the other hand divided the collaboration types into six categories (Table 2.6):

- Personal informal relationship;
- Personal formal relationships;
- Third parties;
- Formal targeted agreements;
- Formal non-targeted agreements;
- Creation of focused structures.

Table 2.6: A Taxonomy for Industry-University Interorganisational Relations; Source: Bonaccorsi and Piccaluga (1994)

Type of Relationships	Linking Mechanisms (Type of University Service)
Personal Informal Relationships	Individual consultancy (paid for or free) Informal exchange forums and workshops Academic spin-off Research publications
Personal Formal Relationships	Scholarships and postgraduate linkages Student interns and sandwich courses Sabbatical periods for professors Exchange of personnel
Third Parties	Liaison offices Industrial associations Applied research institutes General assistance units Institutional consultancy (university companies)
Formal Targeted Agreements	Contract research Training for employees

Type of Relationships	Linking Mechanisms (Type of University Service)
	Cooperative research projects and joint research programmes
Formal Non-Targeted Agreements	Board agreements Industrially sponsored R&D in university departments Research grants and donations, general or directed to specific departments
Creation of Focused Structures	Association contracts University-industry research consortia University-industry cooperative research centres Innovation/incubation centres Research, science and technology parks Mergers

2.7 Structure of Industry Demand Side and University Supply Side

For adopting the right innovative partnership approach and assessing the appropriate partnership model, the particular characteristics of the industry demand side and university supply side of each partnership type, and the various linking mechanisms must be assessed for the various countries.

The following lists are some keys, which related with demand and supply side concept:

Demand side factors in general include: (Ramanathan, 1994)

- Profitability of the investment in an innovation
- Size of the investment required to adopt the innovation
- Utility-adjusted price ratio between the innovation and its competitor
- Technological complexity of the innovation
- Age, condition, and rate of obsolescence of the existing capital equipment that an innovation seeks to displace
- Quality characteristics of the innovation
- Type of interaction of the innovation with other concurrent innovations (independent, complementary, contingent or substitute)
- The number of companies who have already adopted and not yet adopted the innovation
- The social, psychological, economic and location characteristics of those potential adopters.

Especially demand side factors related with university, there are some demands such as training, research for technology development, technical advice and seminars/courses.

Supply side factors in general include: (Ramanathan, 1994 a)

- Supplier actions pertaining to market selection, market segmentation, promotional communications, pricing and infrastructure development (after sales service, spare parts supply, trouble shooting and so on)
- Actions of related private and public organizations such as infrastructure development, promotional communication and regulation/promotion of the innovation

In addition, for adopting the framework of the thesis, Wu (1999) proposed the research framework of Industry-University Research Cooperation to identify Industry-University Research Cooperation System in Taiwan. The research framework for his study is shown in Figure 2.2.

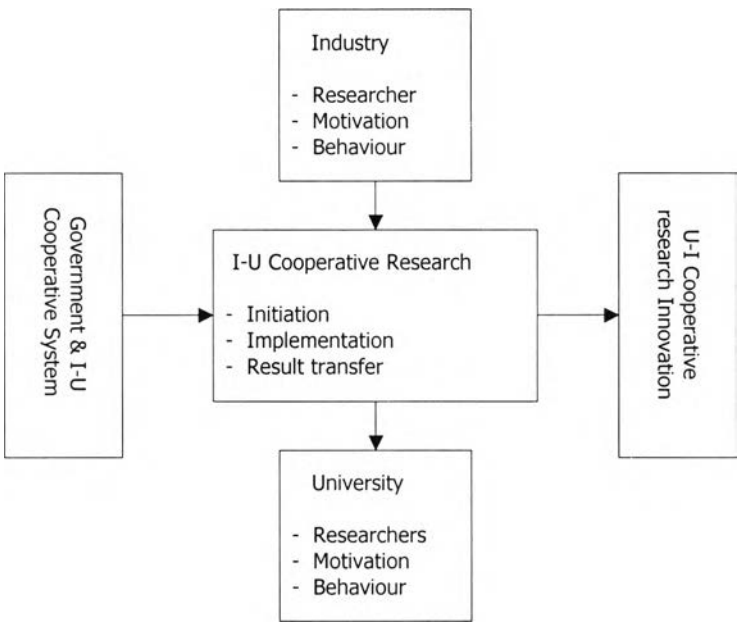

Figure 2.2 The Research Framework of Industry-University Research Cooperation; Source: Wu (1999)

2.8 Evolution of Technology Transfer

Cheng (1994) divided the technology transfer into three phases (see Figure 2.3).

Phase I: short-term relationships lasting a few weeks which consists of Training Programs, Symposia, Publications, Grants, Fellowships, Scholarships and Donations. Most of the producers focuses on low-cost production and were reluctant to face long

range uncertainties involved with research and development. Academia kept to the status quo, occupying itself with teaching and research for their own sake.

Phase II: medium-term relationships from 1 to 3 years and consists of such mechanisms as Patent Licensing, Sponsored Research, Faculty Consulting and Personal Exchanges.

Key developments in this new phase of interaction include the following.

- Establishment of industrial liaison offices
- Growth of contract research
- Encouragement of faculty consulting.

Phase III: long-term relationships that would last for many years as in the form of Technology Parks and Industrial Incubators. In this stage, relationships will likely to be characterized by long-term interactions involving the creation of not just new products or processes, but entire new knowledge-intensive industries.

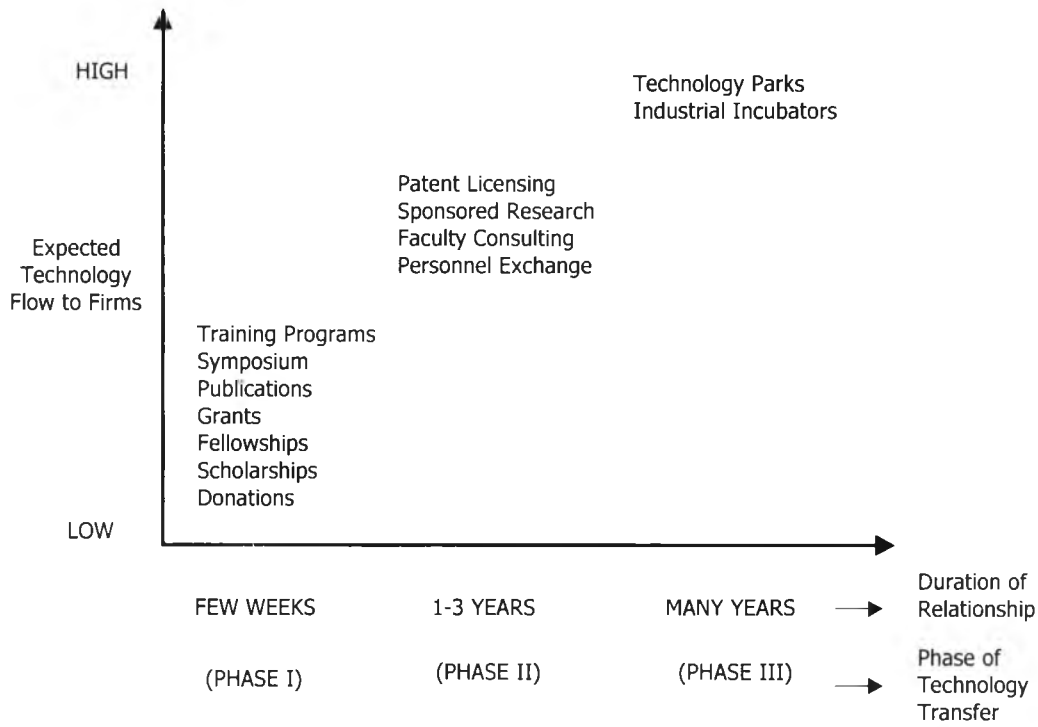

Figure 2.3: Linking Mechanism Phases in Technology Transfer

2.9 Obstacles

There still exist some obstacles and potential risks for the industry-university interactions. Table 2.7 contains a list of major sources of potential risks of industry-university relations. These risks will cause obstacles to industry-university partnerships.

The major obstacles include: (1) value conflict; (2) information dissemination restrictions; and (3) intellectual property rights (Brodsky, 1979; Peters and Fusfeld, 1982; Krebs, 1984).

Table 2.7: Major Area of Potential Risks of Industry-University Partnerships

1. Reduced university autonomy
2. Intermingling of public and private funds
3. Appropriateness of the research
4. Openness and publication
5. Patents and Licenses
6. Conflict of interests
7. Conflicts of commitment

2.9.1 Value Conflicts

The university and industry exist for different purposes. The former exists to foster an environment conducive to advancement of knowledge, the free inquiry, and exchange of ideas. Universities regard themselves as responsible to "the public" with their work contributing to some large or educational purpose. On the other hand, a company or business activity exists to offer a service or product to society and on this basis, to make a profit, which sustains the employment of its personnel, and provides return to those investors, primarily stockholders (Brodsky, 1979).

In addition, academic researchers are sometimes described as having a disdain for the profit orientation and for research, which is too narrow or market-oriented. By contrast, industrial researchers are said to view their academic colleagues as "ivory tower" types who are excessively theoretical and who care too little for their work's application (Baldwin and Green, 1984).

The two following tables show the different orientation between industry and university (see Table 2.8), and conflicts (see Table 2.9) regarding Shenhar's analysis of the relationship between a large aerospace company and a school of business administration, analysed the PROMIS project (Project Management Improvement Study) where industry and university learned together.

Table 2.8: Different Orientation Between Industry and University; Source: Shenhar (1993)

Difference in	Industry	University
Attitudes & Values	Business attitude	Scientific attitude
	Economic consideration	Professional consideration
	Satisfying the customer	Do good research
Objectives	Organisational effectiveness	Excellency in research
	Short term result	Excellency in teaching
Outputs	Cost effective products & services	Research result
		Theory
		Academic degree
Standards & Rules	Organisation rationality	Professional ethics
	Organisational rules	Scientific norms
Recognition & Rewards	For contribution to company goals	For scientific achievement
Knowledge & Learning	Application of knowledge	Contribution to knowledge
	Learning only if needed	Continuous learning

Table 2.9: Conflict in Attitudes, Values & Objective Between Industry & University; Source: Shenhar (1993)

Industry		University
Short-term	versus	Long-term
Business & Profit Driven Values	versus	Professional & Technical Values
Organisation Effectiveness	versus	Challenging & Interest Work
Integration	versus	Differentiation
Application of Technology	versus	Accumulation of knowledge

2.9.2 Information Dissemination Restraints (Based Substantially on Peter and Fusfeld (1982)

The faculty and researchers of academe have usually treated knowledge as a freely disseminated outcome of research. In industry, however, new knowledge is properly treated as private property and the result of an investment in research, and thereby should be utilised in the best interests of the company.

Freedom to publish is fundamental to the university. University research, including research sponsored by industry, is governed by the tradition of free exchange of ideas and prompt transmission of research results.

However, most universities allow a firm sponsoring research some time to review manuscripts resulting from the sponsored research for comment to ensure that they do not contain company's proprietary information. The pre-publication review allowance, varying from university to university, is usually for one to six months.

2.9.3 Intellectual Property Rights

A large percentage of academic research historically has been funded by U.S. federal government, which retains the ownership of patent arising from federally funded research. As the U.S. government licensing of these patents was almost entirely on a non-exclusive bases, many patents were not developed into commercial goods or services because non-exclusive licenses did not give the industrial firms the required protection to justify the costs of development (Chermside, 1985).

Ditzel (1988) pointed out that in the industry-university research interactions one of the key concerns of an industrial firm is whether patent rights will be available to that firm for license on the new technologies or products, which may arise under university research it sponsors. According to roundtable report by National Academy Press (Macomber, 1991), industrial firms do always complain about the difficulties in negotiating intellectual property rights and patenting and licensing agreements in industry-university partnerships. However, the patent issues are not only critical to industrial firms but also to universities. For a university, the filing of patent applications on the research inventions is essential to attract licensing interest from industrial companies for commercial development and to attract funding for further research relating to the invention. Since many university researchers do not perceive the disclosure of possible patentable inventions as being part of their research mission, most research universities have attempted to structure patent administration programs that would not place undue burdens on the academic researchers.

In 1980, the U.S. Congress passed the Patent and Trademark Law Amendment Act, which allows the university to retain the rights of the inventions, and requires universities to share net royalty income from their inventions. However, there still exist some difficulties to both sides in negotiating the licensing agreements. One source of the difficulties, for example, is the definition of an invention 'arising" under the research grant (Ditzel, 1988). Companies often request that the definition of an invention 'arising "includes all patenable inventions either conceived or reduced to practice under their full or partial funding. But university acceptance of such a provision without limitation could give rise to conflicting obligations on the part of the university. Another difficulty is that the 1980 legislation still restrict and limit the grant of exclusive rights to persons (other than small business) to a period of five to eight years.

2.10 Critical Success Factors of the Relationship (Based Substantially on Frye, 1993 and Gee, 1993)

To make the relationship between industry and university a success for both partners, the following principles should be observed.

Frye (1993) has observed industry-university cooperative research, which yields dividends and brought the experience of Chrysler Corporation to identify some critical success factors for that cooperation.

1) Every project must have a champion. It means every project needs a person to keep the project on the right direction. Without industry participation, research activity may result in an excellent solution to a problem that does not exist. Thus Frye established the rule: 'No champion, no project'.

2) Good research proposal is critical to the success of a project. The proposal must identify clearly the work desired, set forth all major requirements, indicate what the sponsor will furnish, what deliverables the principal investigator is expected to provide, and should not be excessively detailed.

3) A proper project length is important. Shorter projects are better than longer ones. Project length usually one or two years, maximum three years to minimise problems with the personnel re-assignment. Lengthy research divided into shorter projects, evaluate every period before making an extended commitment, finally the projects be supplemented to complete the whole research.

4) Secure complete funding at the time of the project award. The research should not be subject to the uncertainties associated with annual budgeting. It is unfair to jeopardize the planning simply to meet the short-term variations of budget.

5) Regular project monitoring is essential. This monitoring is to ensure the research is properly directed and on schedule. Better are face-to-face meetings quarterly or twice a year than conversations on the phone. Brief written progress reports should be provided monthly.

Another researcher, Gee (1993), suggested the following critical success factors after studying technology transfer effectiveness in industry-university cooperative research, which is observed in the Centre for Interface Engineering (CIE) at the University of Minnesota, the USA.

1) The university must have high quality faculty and research programs and must be willing and able to work with industrial companies, have a strong commitment to cooperative industrial research, willingness to work with industry, guarantee no interfering with primary goal as educators/researchers, flexible & negotiable position, deal with intellectual property rights, maintain professional respect between the faculty members & industrial researchers, thus bringing relevant and useful technological insight to the company.

2) The university must have a significant stake in the cooperative research effort, have an equity position in the effort, act as a true partner, invest physical facilities and equipment, people and money.

3) The university technology transfer function must be managed in a proactive and aggressive manner with clearly defined responsibilities, objectives and accountability. Technology transfer function cannot be left to chance or to be totally reactive. Staffs must devote all of their efforts to the technology transfer function.

4) The technology transfer function must be managed by a person with significant high-level industry experience. Technology transfer managers must have significant industry experience, having a technical background (research or production) is essential, and also knowledge about the working environment inside industry is crucial to successful implementation.

5) Participating companies must have a significant stake in the cooperative research effort. Business companies should do more than provide money, but also assign specific people to interact with the university. The liaison person must have the time, ability, interest, responsibility and authority to interact with the faculty member.

6) Participating companies must share their technical needs and requirements with faculty to the extent allowed by proprietary situations. A cooperative research program should be involved primarily with generic problem or phenomena and handled by contractual arrangement with individual faculty member or done at the company's laboratories. These factors depend on the goodwill of top management of the industry.

7) Technology transfer takes place most effectively through person-to-person interaction. Every effort should be made to promote the long term joint research projects carried out either at the university or company laboratories with both industry and university researchers in residence for extended periods and working together on research projects of mutual interest.