Innovation networks in a complex product system project: the case of the ISDN project in Indonesia

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Abstract: The innovation in simple or mass products has been studied widely. This study is to explore the innovation network in a complex product, namely an Integrated Services Digital Network (ISDN) project in Indonesia. This project is driven and implemented by network partners consisting of a domestic telecommunication operator, switch suppliers, CPE suppliers, a consultant, experts, an international network operator, an investor, a regulatory body and users. This study shows that a developing country has the capability to manage a complex product project. The level of technological capability to manage it, is likely to be different according to the country's technological and economic development level. It has also identified that the majority characteristics of ISDN confirm the hypothetical characteristics of a complex product.

Keywords: Innovation; network; ISDN; complex product system; project; telecommunication; Indonesia.

Reference to this paper should be made as follows: Gunawan, Igel, B. and Ramanathan, K. (2002) 'Innovation networks in a complex product system project: the case of the ISDN project in Indonesia', *Int. J. Technology Management*, Vol. 24, Nos. 5/6, pp.583–599.

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1 Introduction

Innovation process models have mainly focused on the internal firm environment and do not pay adequate attention to external factors that mostly are beyond the direct control of firm management. New technologies and system innovation reinforce the trend that firms become more dependent on external sources of technological innovation. This trend can be seen in some industries such as aerospace, computers, biotechnology and telecommunications. Networking in the Russian aerospace industry involved the Ministry of Defence, a design bureau, manufacturing plants, research institutes, specialist universities, testing centres and the Aircraft Certification Authority [1]. The case of the regional computer industry network in Boston reveals complex interrelationships among computer firms, research universities, research laboratories, electric and component firms, software firms, and specialised business services [2]. Biotech firms collaborate with research universities, medical research institutes, suppliers of equipment, specialised business services, funding institutions, venture capital firms, government and international organisations. In the telecommunications industry, a major project for global mobile communication such as Iridium and Inmarsat rely on global networking, involving many parties across the world.

Those large and complex projects took place in advanced technological countries. This paper will try to explore one project of a complex product, that is an ISDN project, in a developing country – Indonesia. ISDN (Integrated Services Digital Network) is a network, in general, evolving from the telephone network, which provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice services, to which users have access by a limited set of standard multi-purpose user-network interfaces (defined by the Consultative Committee on International Telegraphy and Telephone). The objective of the ISDN is to enable universal communications among different types of users with various types of media to transport over a single network technology [3].

This paper aims to describe and analyse the innovation network and the innovation characteristics of the ISDN project related to the innovation characteristics of complex products. Because research in this area is not structured yet, this study is based on an in-depth case analysis [4]. For this research, relevant information was obtained through unstructured interviews with some key persons from different parties involved in the project. In addition, various historical records and related documents were reviewed to complete our research findings.

This paper first reviews the previous literature on the concepts of a complex product and network, and the motives and risks of technological collaboration in Section 2. Section 3 will discuss the innovation network within the case study project. Furthermore, we will summarise some lessons for other developing countries considering introducing ISDN in Section 4. Finally, Section 5 will conclude this study.

2 Innovation network and CPS

2.1 Definition of CPS

The development of technology is becoming more and more complex and sophisticated, and the product as the output of the transformation process by technology is also becoming more complex. Such outputs are called Complex Product Systems [5], Complex Product [6], Complex Technology [7], Complex System [8,9], Large Technical Systems [10] and Complex Engineering Project [11]. These terms show a similar pattern for the product made of many interconnected customised components, and exhibit emerging properties through time as a response to the evolving needs of large users [8]. They include very high cost, complex, high technology goods, infrastructure and systems [5,12]. Such products, for example, are telecommunication networks, flight simulators, high speed trains, aircraft, military systems, base stations for mobile communications, banking information systems, and intelligent buildings. Furthermore, the term Complex Product Systems (CPS) will be used in this paper.

In many dimensions, characteristics of CPS contrast sharply with mass production goods. These differences imply distinctive forms of innovation and organisation. Complex product systems embody at least three general characteristics [8]. Firstly, they are made up of many interconnected, often customised, elements (including control units, sub-systems and components), usually organised in a hierarchical way. Secondly, CPSs exhibit non-linear and continuously emerging properties, whereby small changes in one part of the system can lead to large alterations in other parts of the system. Thirdly, there is a high degree of user involvement in the innovation process, through which the needs of the economic environment feed directly into the innovation process.

To distinguish CPSs from simple/mass products in more detail, Hobday [5] proposed six dimensions:

1 product characteristics;

2 production characteristics;

3 innovation process;

4 competitive strategies and innovation management;

5 industrial structure, organisation and evolution; and

6 market characteristics as shown in Table 1.

Table 1 Characteristics of CPS [5]

Product characteristics	*Production characteristics*
Hierarchical/systemic	Project/small batch
Complex interfaces	System Integration
Very high cost	Software engineering intensive
Products cycles last decades	Scale-intensive, mass production not relevant
Multi-technology inputs	
(Many) tailored components	
Software-intensive	
Complex, multi-functional	
Non-linear properties	
Upstream, capital goods	
Innovation processes	*Competitive strategies and innovation management*
User-producer driven	Focus on product design and development
Business to business	Organic
Highly flexible, craft based	System integration competencies
Innovation and diffusion collapsed	Management of multi-firm alliances
Innovation paths agreed *ex ante* among suppliers, users etc.	
People-embodied knowledge	
Industrial structure, organisation and evolution	*Market characteristics*
Highly complex institutions	Duopolistic structure
Project-based multi-firm alliances	Few large transactions
Temporary multi-firm alliances for innovation and production	Non-market mechanisms vital
Long-term stability despite radical technical change	Institutionalised/politicised
	Heavily regulated/controlled
	Negotiated prices
	Often non-contested

2.2 *Innovation network, motives and risks*

An external source of innovation resources is a vital issue in CPS projects because the CPS producer does not have all the skills and resources to handle all sub-systems and technologies required. The fact should not be neglected, however, that external sources are not a substitute for the firm's internal resources but rather complement them. Many studies indicate the important role of external sources for successful innovation. The growing number of business firms relying on external sources stimulated a wide range of theoretical explanations. Many different terms are proposed such as collaboration [13], technological interweavement [14], technological collaboration [15], network [16–18], strategic technology partnering [19], and innovation network [20].

Technological collaboration can take many forms. Focussing on the innovation perspective, some major forms of collaboration are:

- joint ventures and research corporations
- joint R&D agreements
- technology exchange agreements
- direct investment motivated by technology factors
- licensing
- sub-contracting
- production sharing and supplier networks
- research associations
- government-sponsored joint research programs
- computerised data banks
- value-added networks for technical and scientific interchange [18]

Dodgson [15] identified some motives of technological (innovative) collaboration as follows:

- linkages in the innovation process
- high costs of technological development
- technological complexity and novelty
- increasing application of information technology
- technological risks
- the nature of technological knowledge
- speed to market
- creating a technical standard

CPS project by nature involves many different parties. Therefore, different motives in collaboration may occur.

The basic question regarding the reasons for technological collaboration is relevant to the understanding of both practical issues in strategic management as well as to theoretical knowledge of the organisational boundaries of the modern firm [19]. In collaboration, firms share activities, and know-how, as well as future income. There is a common belief that it is very difficult to make cooperation agreements work. Understanding the motives of cooperation better will reduce the risk of failure.

The motive for collaboration in creating or setting technical standards is very important in a CPS project. On the international level, the technical standards, for example, are handled by the International Organisation for Standardisation (ISO), the International Electrotechnical Committee (IEC) and the International Telecommunication Union (ITU) [21]. On the industry level, standards can be established by voluntary

agreements within an industry or may exist *de facto* in line with the standard of predominating companies through evolving dominant design [15,22]. Reddy [21] showed the importance of standards for the development of a new technology, such as ISDN and CIM (Computer Integrated Manufacturing). An ISDN project requires cooperative action on the part of phone companies, satellite suppliers, microwave vendors, local area network companies, and value-added network operators. The CIM industry demands cooperative action between mainframe and minicomputer manufacturers and suppliers, turnkey computer-aided design systems, graphics workstations, production systems, unbundled software, system integration services, and other related hardware.

It is expected that collaboration brings benefits for each network party. However, in fact some expectations may not be realised and some problems may emerge during collaboration. Understanding the disadvantages and risks of collaboration is important to develop guidelines to reduce the risks. Several studies discussed the risks and disadvantages of collaboration in innovation projects, such as in information and communication technology [13]. The most critical risk is leakage of information to a partner. Sensitive data leaking out can refer to a firm's skill, market intelligence, experience and general tacit knowledge that may form the basis of its competitiveness. Collaboration will reduce the direct control of the whole innovation process by one company. Collaboration may lead to longer development time. Different objectives or motivations of each party can create conflict. Collaboration can create potential competitors for the firm. It also often happens that partnership with 'a key supplier' will create dependency. Unacceptable development costs often happen in collaboration.

Collaboration brings benefits as well as risks. Therefore, it is critical for CPS producers to weigh the benefits and disadvantages of any collaboration.

3 Case study: ISDN project in Indonesia

3.1 Backgrounds

The Indonesia telecommunication market is in the midst of rapidly changing environments of deregulation, competition and privatisation. PT Telkom (PT means Co. Ltd.) has broken up its monopoly for several telecommunication services such as international telecommunication services, mobile communication and wireless communication. Now, PT Telkom, as a state-owned company, is a telecommunication service provider primarily for the local and domestic long distance telephone service. Two companies, namely PT Indosat and PT Satelindo, manage the international telecommunication service.

In the telecommunication equipment manufacturing area, government allows competition in switch, transmission and customer premise equipment (CPE). For the switches, government allowed three foreign companies to enter the market, namely AT&T, NEC and Siemens. These three companies through joint ventures with local partners have established manufacturing plants in Indonesia. Through this policy, the transfer of technology to local companies is expected to occur.

In a period of rapid technological change, more sophisticated demand and high competition, new product development is a critical issue for the telecommunication service provider. PT Telkom and other telecommunication institutions responded to this

challenge by implementing ISDN in Indonesia. The purpose of ISDN introduction in Indonesia was:

- To avoid the urge to establish more dedicated networks (networks for specific service) for data services and special business services at a high cost and with poor utilisation.
- To provide basic data services for business subscribers with efficiency, quality, and in sufficient numbers as far as subscriber access is concerned.
- To provide an advanced telephone service, which offers some attractions to subscribers by means of selected supplementary services.
- To provide a basic future oriented multi-purpose resource for the provision of more advanced services such as video telephone, videotext and other more sophisticated services in the near and the far future.

3.2 Development stages

The main activities of the ISDN project in Indonesia were conducted in the following time frame as presented below:

- Idea generation (1985): initiated in the seminar on ISDN;
- Pre-feasibility study (1989): conducted by PT Pan System;
- Developing standard (1992–1993): developed by working group on standardisation of Project I2 (ISDN & IN/Intelligent Network);
- Implementation agreement among PT Telkom, PT Indosat, PT INTI, DG Postel;
- Switch manufacturing by PT INTI-Siemens, NEC and AT&T;
- Installation of domestic exchange/network: done by Regional divisions of PT Telkom;
- Installation of international gateway exchange: done by PT Indosat and PT Satelindo;
- CPE market penetration: distribution of imported CPE;
- Launching of commercialisation (8 September 1995): with the commercial name PASOPATI;
- Service application development: done by DivRisTI (R&D division of PT Telkom);
- Expansion into new areas.

Those activities did not happen strictly in sequential order and some activities took place in parallel. These should not be seen as activities of a unit project but appeared as a combination of projects and ordinary activities of divisions. The outcome of this project is an ISDN network that can provide a variety of services.

The implementation – commercialisation stage of the ISDN project can be divided into three phases [23]:

- Phase I (1995–1996)

  ISDN lines were available in a limited capacity in five big cities (Jakarta, Bandung, Surabaya, Medan and Batam). PT Telkom as an ISDN domestic operator offered ISDN service to the corporate customer network (CCN) in those cities. Here, ISDN was available at selected places where industry, trade, tourism and administration were concentrated.

- Phase II

  Expansion of ISDN network and service within those five big cities was carried out. Connection capacity will be enlarged. Furthermore, the ISDN network and service will be expanded to residential users.

- Phase III

  The ISDN network and service will be expanded to other cities.

In the real situation, this implementation for each phase depends on customer need in each area. The implementation of phase II and III in each city/area may not happen in sequential order. Now, PT Telkom is working on implementation development to enlarge ISDN lines in wider areas. DivRisTI as R&D division is conducting research to develop service application. It aims to package ISDN applications for ease of customer selection and use.

3.3 Roles, motives and problems

There are many different parties contributing to the implementation of the ISDN project, as follows:

Switch suppliers

According to government regulation, three companies are allowed to be switch suppliers, namely Siemens (Germany), AT&T (USA), NEC (Japan). These three companies have set up manufacturing sites in Indonesia through joint ventures with domestic partners. Siemens in a joint venture with PT INTI (national telecommunication manufacturing company) has been present in Indonesia's telecommunication development for a long time. The current digital switches are made on a modular basis. Therefore, they can be upgraded for ISDN by adding ISDN cards.

Consultant

Pan-System, a national consultant in the telecommunication area, was greatly involved in the ISDN project. Pan-System was assigned by government (DG Postel as a regulatory body) to do a feasibility study for ISDN introduction. Furthermore, Pan-System was also involved in the standardisation phase within project I2. The cooperation between DG Postel and Pan-System was not based purely on business but more on a continuing partnership.

Experts

Experts from academic institutions, namely the University of Indonesia (UI) and Bandung Institute of Technology (ITB), are involved in the Project I2 (ISDN – IN).

International network operators

There are two international network operators, namely PT Indosat and PT Satelindo. PT Indosat manages the interconnection of the national ISDN with ISDN in other countries. This company has pioneered international ISDN connections to countries in Asia, Europe and USA as depicted in Table 2. This cooperation aims to make a link to the innovation process and to get market access. PT Satelindo as an operator of Indonesian satellite and cellular telephone systems, has implemented international ISDN interconnection to several countries such as the USA, Denmark, UK, Germany, Australia, and Hongkong, Singapore and Malaysia. Satelindo's motive is to give support to ISDN users of PT Telkom and PT Satelindo itself, to ISDN users abroad.

Table 2 International ISDN interconnection by PT Indosat in 1997 [23]

Country	*Operator*	*Interconnection*
1 Germany	Deutsche Telekom AG	Direct
2 South Korea	Korea Telecom (KTA)	Via SingTel
3 Malaysia	Telekom Malaysia	Direct
4 New Zealand	TNZI	Via Telstra
5 Philippines	PLDT	Via KDD
6 UK	BTI	Via Neth. PTT
7 Australia	Telstra	Direct
8 Japan	KDD	Direct
	IDC	Direct
	ITJ	Direct
9 Singapore	Singapore Telecom	Direct
10 Netherlands	PTT Netherlands	Direct
11 USA	AT&T	Direct
	MCI	Via Neth. PTT
12 Taiwan	CHT	Direct
13 Switzerland	Swiss Telecom	Direct
14 Hongkong	HKTI	Direct
15 Belgium	Belgacom	Via Neth. PTT
16 Thailand	CAT	Via KDD
17 Norway	Telenor	Via Neth. PTT
18 Denmark	Teledanmark	Via DTAG
19 Austria	PTT Austria	Via DTAG

Investor

As a public company, the budget for the ISDN project came from PT Telkom itself.

Regulatory body

The regulatory body is the Directorate General of Post and Telecommunication (DG Postel) which is under the Ministry of Tourism, Post and Telecommunication. The main regulatory issues to be reviewed were:

- Regulations concerning network and terminal provision,
- Regulations concerning service provision,
- Regulations concerning charging.

One critical regulation was about the terminal sector (CPE) which was fully liberalised. It means that PT Telkom does not provide terminal equipment. Therefore, users can buy the terminal equipment in the market. The relationship between PT Telkom and DG Postel is guided by the motive to create standards and specifications. The involvement of regulatory body is a must because telecommunication products require national adaptation.

International standard body

The National ISDN standard is based on the ITU-T (International Telecommunication Union – Telecommunication sector) standard that is widely adopted all over the world. In this project, there is no direct personnel involvement from ITU-T.

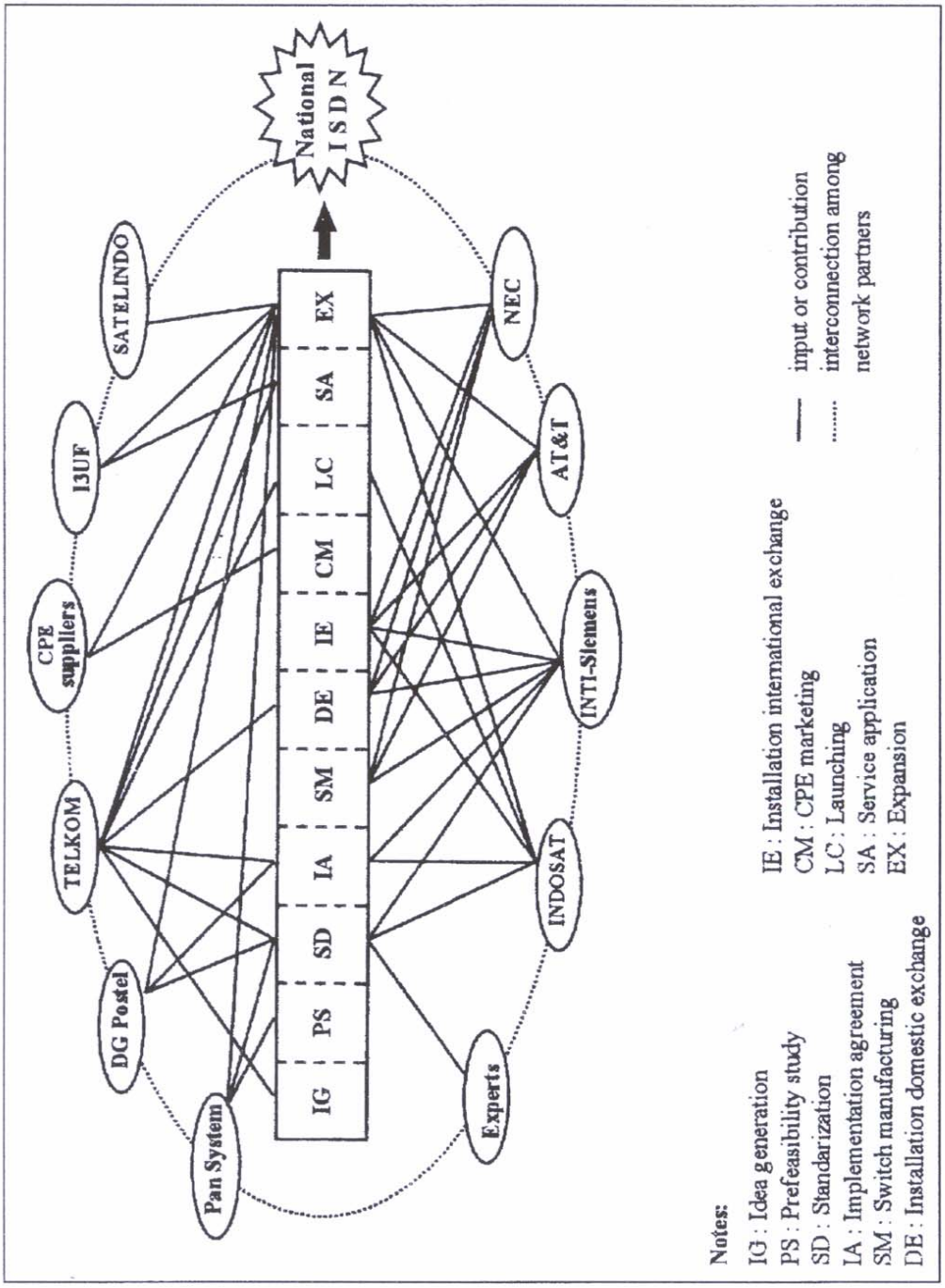
Users

Users were not involved directly in the early ISDN implementation. However, the user needs had been identified during the feasibility study. In 1995, an independent forum called Indonesia ISDN & IN User Forum (I3UF) was established. In this forum, the network operators, suppliers and users discuss problems and ways to promote ISDN & IN.

Among these network partners, the switch suppliers are regarded as the most critical/important partner. The reason is that ISDN development depends heavily on the supplier/manufacturer to upgrade the existing digital switch. The second critical partner is the regulator because all regulations for ISDN implementation are issued by this organisation.

Figure 1 shows the ISDN innovation process in Indonesia. Eleven main activities are drawn in boxes with dashed lines as partitions which means these activities are not in a rigid time sequence. Some activities might be overlapping such as switch manufacturing and CPE market penetration. Some activities still continue such as service application development and CPE market penetration. The parties shown in the network have direct interaction with the innovation activities. The international standard body is not included because there is no direct personnel involvement. The solid lines connecting each party to a specific activity represents each party's contribution to the innovation process. The elliptical dotted line indicates the interconnection or interaction among the network partners. The outcome of the ISDN project is a national-ISDN.

Figure 1 Innovation network of the ISDN project



The main characteristics of ISDN are:

- complex technology,
- a wide application,
- applied in a wide area, and
- needing a technical standard.

Therefore, cooperation is guided by such characteristics. The linkages among PT Telkom and switch suppliers, Pan-System, experts, international network operators, DG Postel

and the international standard body have focussed on the acquisition of complementary technological capabilities and resources. Here, technology is regarded as having four basic components: physical facilities, human abilities, information and an organisational framework [24]. The motive to gain market access is also dominant in the cooperation between PT Telkom and international network operators. It is reasonable because ISDN (or telecommunications in general) is not a local service but a global service.

The innovation of ISDN, as a telecommunication infrastructure, brings benefits to both network operator and customers such as:

- Speed and quality: Information can be transmitted with better quality, shorter time and greater volume than the existing service.
- Efficiency: ISDN offers one network for various services. Customers may pay a lower cost for ISDN services rather than for all dedicated services separately.
- Flexibility: ISDN uses a standardised interface that can be used with various terminals.
- Cost saving: Integrated services means reducing cost to get various services from several operators. Moreover, high speed data transmission results in shorter transmission time that leads to cost saving.

This study found some problems in the innovation process as follows:

- Delay in implementation because of delay in upgrading switches by supplier,
- Difficulties for users to choose CPEs according to the ISDN service application required,
- Delay in CPE approval by the regulatory body,
- Defects on the subscriber loop that had not been detected before,
- High price of CPE because of low demand.

Those problems are not specific to the network but a proper coordination and commitment among parties involved might minimise them.

3.4 Characteristics of ISDN being as a CPS

Based on the framework proposed by Hobday, the characteristics of ISDN are analysed. The majority of CPS characteristics can be found in the ISDN as summarised in Table 3. In the product characteristics, ISDN can be seen both as a tangible product and an intangible product with many service applications and very long operational time frame. ISDN implementation requires multi-technology inputs and large investment. Regarding the production characteristics, the activities are managed as projects and done in coordination with multi-parties. The characteristics of the ISDN innovation process show that the process does not take place within a single project organisation. It is driven by multi-parties and requires knowledge embodied in their personnel. This innovation process is centralised in the early stages to create a standard and then decentralised in the implementation stage. This project is driven by economies of scope, which are indicated by upgrading the existing digital telephone network. The organisational form is a temporary project-based organisation. Overall, ISDN is highly regulated in terms of the technical specification, network, and charging.

Table 3 also identifies some characteristics of the ISDN innovation process that do not confirm the assumed characteristics suggested by Hobday. This means that the characteristics of the ISDN innovation process are similar to the process of simple product innovation. For example, business to business transactions could not be identified in this case because the producer (system integrator) is also a user (network operator). This characteristic is a central element for a simple product, namely a business to customer transaction. As a consequence, the diffusion and innovation can be identified and separated clearly, as in the case of a simple product. The ISDN service application is offered in a monopolistic market for a regulated price.

Table 3 The characteristics of ISDN being as a CPS

Product characteristics	*Production characteristics*
• array	* project activities
* increasing complexity	* system integration
* tangible: array network	* integration: existing & new system/equipment
* intangible: service provision	• software engineering intensive
* not the final product	• coordination of operator, manufacturer and regulator inputs
* high cost/investment	
* long product cycle	
* software intensive: integration of telecommunication and IT	
* multi service application/function	
• multi technology inputs	
* can be expanded	
Innovation processes	*Competitive strategies and innovation management*
* not within single project	* driven by economies of scope
* operator, supplier, regulator driven	* cooperation of multi parties
* international standard/technical specification	* focus on own network system design and development
* people embodied knowledge	* continuous innovation/improvement
* centralised in very early stages, decentralised in implementation	
* innovation continues through application together with diffusion phases	
‡ producer-user same actor	
‡ business to end user	
Industrial structure, organisation and evolution	*Market characteristics*
* project-based multi parties agreement	* highly regulated
• temporary project-based organisation	* monopolistic/duopolistic
	* regulated price
	‡ market mechanism transaction

Note:

weakly supported

* strongly supported

‡ contradiction with the CPS characteristic

4 Lessons for other developing countries in the region that are about to introduce ISDN

Indonesia's experience in implementing ISDN can be a valuable lesson to other countries that will introduce ISDN. There are five aspects that should be considered in introducing ISDN, as follows:

Rationale for implementation

There must be strong economic and technological reasons to implement ISDN. Economically, implementation of an integrated network/service should be more beneficial than the implementation of a dedicated network/service at a high cost. Moreover, there must be potential customers who can afford ISDN services. Technologically, the characteristics of the existing digital network such as areas covering the quality of transmission lines and switches should be considered.

Regulatory issues

Regulatory issues are very important in implementing ISDN, which relies heavily on technical specifications and administrative or legal issues. These regulatory issues include technical standards, the network operator, the charging policy and terminal approval. The regulatory body must issue these items during the ISDN project. Delay in addressing some aspects will cause problems.

Network partners

ISDN implementation requires the agreement and cooperation of network partners to support the project. The main network partners consist of domestic and international telecommunication operators, the R&D division, the regulatory body, switch manufacturers and CPE suppliers. In addition, consultants, experts and the ISDN user forum can be included. An organisational structure or committee should be created that involves personnel from these partners. This committee should be able to coordinate, manage and integrate the whole ISDN project activities done by each partner.

Technological capabilities

Technological capabilities needed in the whole ISDN project activities include all network partners' capabilities to support the project. For example, the R&D division should have capabilities to design technical specifications, to design the testing system for ISDN equipment, and to explore ISDN service applications. Switch manufacturers must have the capability to make hardware and software for upgrading the existing digital network. Domestic and international network operators must have the capabilities to design the network system, to install new equipment and to upgrade the existing network, to operate and to maintain the ISDN network, and to market ISDN services. CPE manufacturers must have the capability to produce CPE compatible with the ISDN standard. The details of resources and technological capabilities needed depend on the specific role of network partners.

Marketing plan

It is common in any major technological innovation, that the customer will be rather reluctant to adopt a new product/service at the beginning. A marketing plan should be made carefully to overcome this situation which can lead to slow diffusion rate. This plan should cover issues about the main customer target, promotion strategies and after sales services.

Telecommunication manufacturing company

A national telecommunication manufacturing company is very important in building up the technological capabilities of the country. The liberalisation of the telecommunication market, a WTO agreement, is a big challenge for each country, especially developing countries, to build and develop strong technological capabilities through a national telecommunications manufacturing company. In this case study, PT INTI as a national telecommunication manufacturing company, implemented manufacturing plans on a step-by-step basis, following the philosophy 'to start with the end and to end with the beginning', i.e., to commence with the final product and finish with the initial components [25]. This philosophy is translated into four overlapping stages:

1 technology transfer through licensed production,

2 technology integration,

3 technology development

4 large-scale basic research to support the first three stages and to defend the technological superiority already attained.

5 Conclusion

This paper has focused on the innovation network of a complex product system with the case of an ISDN project in a developing country. First of all, it outlined that the ISDN innovation process in Indonesia was highly dependent on network-partners. This network consists of the domestic and international telecommunication operators, the regulatory body, switch manufacturers, CPE suppliers, consultants, experts and user groups present in a user forum. Each partner plays a specific role in providing different innovative assets. This innovation is initiated by an agreement among the key partners to implement ISDN.

Secondly, the ISDN project can be categorised as a CPS project because it met the majority CPS's characteristics as proposed by Hobday. This study has identified some CPS characteristics that do not fit into ISDN. The reason is that the CPS characteristics proposed by Hobday focus more on a tangible manufacturing product. In fact, ISDN has some characteristics as an intangible product.

Finally, the research shows the capability of a developing country to adopt and implement the CPS project. Therefore, the claim that CPS projects are a domain of mainly Western countries, and that most Asian countries only have the capability to manufacturer simple/mass products, is not true. The level of technological capability to

manage CPS is, of course, different according to each country's technological and economic development level.

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