Technology Assessment in Indonesian Construction Industry

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Abstract. In the last decades the Indonesian construction sector has experienced significant shift in both the size and complexity. The ever-growing size and complexity of construction and infrastructure works often required the employment of non-traditional construction methods and technology. Responding to such needs, however, there remain questions on whether the construction industry is able to respond to such challenges. This paper is to put forward the concept for assessing the technological capability of the Indonesian construction industry. Particularly, it aims to describe how the construction companies evolve in their technological management capability. The assessment will encompass three aspects: technological capacity, development of technology capability and acquisition and adoption of technology. A technology management assessment concept was proposed to determine key factors that influence the way construction companies select and utilize technology to enhance their performance. Although they appear to agree on general path for technology capability development, large contractors seem to be more prepared in formulating the strategies for the utilization and development of technology in the company's strategic plans than those of medium-sized contractors.

1. Introduction

Construction is considered as one of the key industries in Indonesia, that plays important role in creating prosperity for the country as it provides infrastructures for other economic sectors such as agriculture, energy, tourism, manufacturing trades and others [1]. Today, with the increasing demand for infrastructure development, the construction industry has grown to reach 10.4% of GDP, promising works for around 135,000 engineering and construction firms, mostly local SMEs and only around 3% are owned by or affiliated foreign firms. Yet, with the increasing complexity of the industry, this promising potential also susceptible to a threat common to the construction industry, where low productivity, inefficiencies low-skilled workers and a lack of investment in technology and digitalization continue behind other industry [2].

In many countries, although often still considered in a much slower pace than those of other engineering-based industries, the development and utilization of technology in construction has grown rapidly and proven to be effective to improve the industry performance. Various new forms of construction technology are developed, among others, to improve productivity [3] as well as to reduce construction cost, improve safety and sustainability [4]. Therefore, in order to better support the nation development, it is considered important for the Indonesian construction industry to invest more in the development and application of technology.

Despite massive progress in construction investments in both public and private sector, coupled with the advancement of diversified types of construction, how the technology is progressing, what role
and strategy the contractors are playing still vague. To better understand how the technology can play more important role in construction industry in Indonesia, it is deemed important to have a reflection from the players of the industry on how they perceive the technology itself.

2. Historical development of construction technology in Indonesia

The development of construction industry in Indonesia cannot be separated from the nation’s political situation. The development of modern Indonesian construction industry evolved since around the Dutch colonial era, where many buildings and infrastructures, such as railways, bridges, irrigations, ports and roads, were built during that period resembled those of the European modern structures. Historically, the development of construction technology in Indonesia can be categorized into four phases: (a) pre-independent (1940s), (b) early independent era (1945 – 1965), (c) pre-1980s era, and (4) post 1980s era.

In the earlier years after gaining its independence in 1945, the Government of Republic of Indonesia slowly continued with the development of those infrastructure facilities, mainly carried out by a handful of government owned newly nationalized Dutch construction companies in the early 1950s. In that era, practically there were almost no major construction as the country was still preoccupied with its political and nation building. For the following next decades, most of major public infrastructure projects were handled by the government through those government-owned construction companies, whereby those from private sector focused more on the construction of buildings and housings. Technology-wise, the constructions during these periods remained traditional, mostly labour-intensive, sometimes combined with the employment of some imported equipment and technology.

By mid 1970s more imported technology were introduced to the industry by the involvement of engineering and construction firms from foreign countries by through various schemes of government overseas loans for infrastructure development. New modern imported technology and mechanization were gradually applied to various sector of the industry, from high-rise building to large infrastructure construction projects. During the last decades the Indonesia construction industry has also benefited for the application of advanced technology and equipment employed in mining and energy industry. However, those technology advancements remain isolated within large companies (predominantly state-owned), largely remain depended in foreign supply and expertise, with little or no local mastery and development.

In the late 1990s, the Indonesia construction industry entered a new area. The enactment of Construction Law in 1999 was to shift the growth of the national construction industry from government-led infrastructure projects to the private sector. Such a shift was expected to expedite the development of the construction industry, including the advancement of its technology. However, after almost twenty years, the adoption and development of construction technology in Indonesia remains low. Research and development of technology are almost nonexistent, where construction firms are more incline to quick fixed for their business problems. Rather than gradually develop their own technological capability invest, construction firms are more interested in directly procure the readily available technology, mostly from overseas, to meet with their immediate projects’ demands. Therefore, they are more susceptible to their dependent of imported technology. The government effort to alleviate the burden of technological challenges seems to be equally slow. Not only budget for R&D is far below adequate, focus of development is also weak and frequently change. Worse, the adoption of construction R&D output within the Ministry of Public Works is also still very limited [5]. The dissemination of R&D product is mostly limited to small-scaled experimental works in government-support construction project, and almost never elevated into mass-scale industrial sizes. Such condition can no longer be tolerated. In the era of global competition, the construction industry shall strengthen its own technological capability by promoting the development and adoption of appropriate technology that best suits to its needs as well using as much as possible local resources and talents.

3. Assessment of Technology Management Capability

Technology, in general, is defined as the application of science and knowledge for certain purpose; which is for the advancement and prosperity of mankind. As the advancement of knowledge and
sciences, whereby the society and the industry evolve, the technology is also changing, which in turns will impact the industry. Technology Management (TM) can help firms to sustain competitive advantage through their management of technological assets and to adapt changing environmental conditions as well as technological progress [6]. Technology management routines consists of two sets: technology management activities and supporting management activities. At firm-level, understanding the role of technology and how it would impact the industry would assist construction firms in making better decision in investing in technology.

Technology Assessment (TA) is defined as determining short and long-terms impact of implementing technology in terms of economics, social, ethical, legal aspects to provide information for the decision makers in deploying alternative policies [7]. Technology Assessment can be used as strategy to assist in generating appropriate technologies necessary to achieve sustainability in the construction sector [8]. Technological capability refers to the capability of an organization technological strength that affect the organization performance [9]. Technological Capability Assessment (TCA) models are used to evaluate the firm’s capabilities which make it capable in mastering a specific technology or capable of recognizing technologies required for firm’s internal processes [10]. In this paper TCA refers to the assessment of the capability of firms to manage their technological asset, or Technology Management Capability Assessment (TMCA).

In broader view, Technology Management Capability Assessment Model usually consists of three consecutive phases: a) exploration & acquisition of technology, b) mastery & exploitation, and c) development of technology. Technology acquisition is related to determining how a company acquires and adopts certain technologies, in which the implementation of technology seeks to determine the extent to which the application of the technology has an influence on achieving company goals. Assessment to the mastery of technology is used to determine what strategy is taken in order to make full advantage of the technology. Technological learning strategy plays important role in guiding and monitoring the effective application of technology at firm level. This can be achieved through the firm’s internal learning mechanism as well as utilizing external resources, such as through collaboration and networking [11, 12]. Thus, firm’s performance can be related to its technological learning and technological capabilities [12].

Figure 1. Technology management setting.

4. Model for assessment of technology management in construction firms
Better understanding of technology will help construction firms to identify opportunities for improvement and establish strategy to create competitive advantage based on appropriate utilization of technology. For construction firms, technology management capacity building process reflects the
dynamic relationship amongst the construction business environment, the firm’s technological capability and performances. The business environment is external condition by which construction firm must respond appropriately to order to gain an advantage of competition. It refers to the market demands, competition, business and economic conditions, regulatory conditions, as well as environmental and social provisions that govern the industry.

In formal form, technology management capability is part of the firm’s strategy that guides the achievement of firm’s goal through the realization of set of targeted performances. In other words, technology management capability describes what and how technologies are to adopt, master and apply in order to support the achievement of firm’s goal. Further, the development of technological capabilities is part of the company’s policy that includes all the provisions on how technology will be obtained, how to master and employ, and for some extents to improved and developed. In this paper, conceptual framework of Technology Management Capability for construction firms is modelled as follow:

![Conceptual framework for construction firms’ Technology Management Capability](image)

**Figure 2.** Conceptual framework for construction firms’ Technology Management Capability.

The firms’ strategic planning is developed as management tool to respond to business environment. The firm’s strategy composes of technological capacity building program that consists of three sequential stages. The first stage addresses how technology is introduced to the organization. The once the technology is adopted, the next step will be to master and exploit it for the firm’s business purposes. Up to this stage, the firms must decide the extent of how to make use of the current technology, which may eventually become obsolete or ineffective anymore. One logical way is to exploit further through research & development and innovation. Indeed, not all firms would adopt such formal approach, whereby many firms may simply adopt a particular technology without much consideration; as it is urgently needed to finish a project. These are common practices in construction SMEs, where the cost of R&D is considered unaffordable. As a result, the adoption of technology is not deemed as investment for the firm’s valuable asset but merely as part of expendable resources.

5. Methodology
This study aims to find out the strategy in technology management in engineering/construction firms, particularly contractors, in utilizing and developing technology as part of their business processes. This was determined through soliciting their opinions and experiences related to the utilization and development of technology through a set of questionnaires. A structural model was proposed to examine the dynamic of technology management capability of construction firms, based on the conceptual framework derived in Figure 2. The model comprises of 8 variables with a total of 25 latent variables derived from 123 indicators. The respondents are practitioners in construction firms, that were grouped into medium and large firms, to determine whether the two groups took different development strategy in their technological capacity. For similar reason, respondents were then grouped in accordance their
The technology management capability model is composed of three sets of variables. Business environment variable is to determine how care the contractors are with the dynamic of the industry they are facing when making decision about the business. Firm’s strategy variable is used to find out whether contractors formally device strategic steps in response to the dynamic of the industry. Development of technological capability is to learn any initiative of taken by contractors with respect of using and developing technology to response to the dynamic of the construction industry. The next set of variable is Technology acquisition and learning which are measured using variables; Exploration of technology variable determines how contractor is getting information of technology, whereas Acquisition of technology variable is used to understand different ways of contractors in adopting and mastering technology, while Internalization of technology is used to understand the mechanism by which the contractors are deploying the technology prior to its implementation. The last set of variables is to measure how successful a contractor in employing the technology (Technology capability), which is measured by its business performances.
The model is to be used to test whether technology capability development of large contractors take different path that those of the medium contractors. The path is reflected on the causal relationship amongst variables (table 2).

6. Data and analysis
Questionnaires in this study were distributed through online and traditional mail services to practitioners at managerial level, with an average experience of 15 years in construction of building and infrastructure projects. 100 responses were received from contractor practitioners from 46 large and 54 medium contractors, respectively. Although make up more than 80% of all contractors in Indonesia, small-size contractors are intentionally excluded from the survey since they are mostly relied on labour-intensive and simple construction works.

6.1 The role of technology in contractor business operation
This section is intended to show different orientation towards the use of technology amongst construction firms in Indonesia. Respondents gave their opinions about the importance and/or intensity of various matters related to the application of technology in their companies in the form of rating 1, 3, 5 for low, average and high respectively.

| No | Variable                                    | All   | Large  | Medium |
|----|--------------------------------------------|-------|--------|--------|
| 1  | Business environment                        | 2.87  | 3.00   | 2.76   |
| 2  | Firm's strategy                             | 4.08  | 4.00   | 4.15   |
| 3  | Technological capability development        | 3.79  | 4.96   | 3.35   |
| 4  | Exploration of technology                   | 3.33  | 3.85   | 2.89   |
| 5  | Acquisition of technology                   | 2.88  | 3.37   | 2.46   |
| 6  | Internalization of technology               | 2.96  | 3.37   | 2.61   |
| 7  | Technology capability                        | 3.30  | 3.80   | 2.87   |
| 8  | Firm's performance                          | 3.93  | 4.13   | 3.76   |
|    | Average                                    | 3.39  | 3.81   | 3.11   |

Table 2 shows that, in general, large contractors are quite indifferent from their middle-size counterparts in terms of how they consider business environment in their business operations. Meanwhile, all respondents acknowledge that business strategies play an important role in business management. These two indicate that the business environment may seem to be not fully considered in the contractor's strategy. But when it comes to how they view technology; it seems that large construction firms appreciate the technology more as important asset to their organization than those of the medium contractors.

Technological capability is perceived as important factors by all contractors, which they would use it as the basis for taking anticipate actions. Large and medium contractors acknowledged that clients' needs are the main factor that influence in making policy toward adoption of technology, though they are differ in the mechanism on how to implement such policy. Large contractors seem to be more open on selecting and adapting technology that would also match with their future needs, whereas medium contractors tend to be limiting themselves in responding the clients’ requirements.

Construction machinery and production system are the main priority for large contractors in developing the technology capability. This is evidenced by the existence of large contractors who make investments in the form of purchasing and using various modern construction equipment to handle large infrastructure projects. Most respondents from large contractors acknowledged that they are aggressively exploring the potential adoption of latest-but relevance technology by the own R&D units. In some cases, some them are also engaging in collaboration with academia. In contrast, effort to explore
technology was not so intensive for medium contractors, due to the size and complexity of the work they handle and the cost constraint.

Technology acquisition is an important element of technological capacity development. Most large contractors have formed R & D units with relatively adequate budgets; something that is not available to intermediate contractors. Regarding how contractors handle the needs for construction equipment technology, large contractors take a different approach. They tend to regularly try to improve the equipment they already owned and utilized than relying to technology services from suppliers like what medium contractors would do. Internalization of technology is carried put through company’s internal communication system and training. Large contractors are improving their capability in operating the equipment through training and establishment of knowledge centre. Unlike medium contractors, some large contractors have already established protocol for testing and assess new technology prior to adoption and utilization.

Large contractors assume that technology will have a significant impact on work productivity and quality, while medium contractors feel that technology will significantly impact the safety aspect of construction. Regarding the extent to which contractors exploit technology, large contractors who acknowledge that this will be beneficial and that they are able to utilize and improve their technology.

6.2 Model for Technology Capability Building

Departing from understanding how contractors view technology, it is interesting to know whether the strategy to adopt and develop technology is influenced by differences in the contractor’s background. For this purpose, a structural model that describes the relationship amongst business environment, contractor’s strategy, technology capability building, and contractor’s performance was developed. Structural equation modelling (SEM) technique has been successfully used in various construction issues to study dynamic relationships among observed and latent variables [13, 14, 15]. The SEM framework (Fig 3), consists of a measurement component and a structural component. It is used to determine the extent of exogenous variables (technology capability) measure latent variable constructs, while the structural component models the relationships among latent variable constructs to explicitly model direct, indirect and correlative effects.

![Figure 3. Structural model for construction Firms’ Technology Management Capability.](image-url)
Table 3. Measurement of SEM for Technology Management Capability

| No | Variable                                      | All Comp Reliability | All AVE | Large Comp Reliability | Large AVE | Medium Comp Reliability | Medium AVE |
|----|-----------------------------------------------|----------------------|---------|------------------------|-----------|-------------------------|-----------|
| 1  | Business environment                          | 0.876                | 0.703   | 0.886                  | 0.569     | 0.814                   | 0.523     |
| 1.1| Business challenges/obstacles                | 0.876                | 0.703   | 0.913                  | 0.724     | 0.888                   | 0.799     |
| 1.2| Business issues                               | 0.862                | 0.758   | 0.856                  | 0.749     | 0.876                   | 0.779     |
| 2  | Firm’s strategy                               | 0.924                | 0.590   | 0.937                  | 0.600     | 0.941                   | 0.640     |
| 2.1| Anticipative action                           | 0.934                | 0.590   | 0.937                  | 0.600     | 0.941                   | 0.640     |
| 2.2| Project implementation                        | 0.773                | 0.520   | 0.948                  | 0.902     | 0.943                   | 0.348     |
| 3  | Development of technological capability       | 0.940                | 0.552   | 0.934                  | 0.568     | 0.957                   | 0.650     |
| 3.1| Influencing factors                           | 0.907                | 0.764   | 0.879                  | 0.785     |                         |           |
| 3.2| Learning consideration                        | 0.953                | 0.632   | 0.941                  | 0.640     | 0.957                   | 0.659     |
| 4  | Exploration of technology                     | 0.894                | 0.516   | 0.862                  | 0.516     | 0.901                   | 0.688     |
| 4.1| Category of technology                        | 1                    | 1       | 0.910                  | 0.716     | 1                       | 1         |
| 4.2| Technology aggressiveness                     | 0.900                | 0.818   | 1                      | 1         | 0.811                   | 0.589     |
| 4.3| Priority of technology                        | 0.980                | 0.597   | 1                      | 1         | 0.890                   | 0.622     |
| 4.4| Business intelligent data                     | 0.822                | 0.607   | 1.000                  | 1.000     | 1.000                   | 1.000     |
| 5  | Acquisition of technology                     | 0.848                | 0.525   | 0.843                  | 0.577     | 0.875                   | 0.584     |
| 5.1| Equipment availability                        | 0.742                | 0.590   | 0.750                  | 0.599     | 0.653                   | 0.370     |
| 5.2| R&D approach                                  | 0.858                | 0.751   | 1.000                  | 1.000     | 0.872                   | 0.694     |
| 5.3| Budget of technology                          | 1                    | 1       | 1                      | 1         | 1                       | 1         |
| 5.4| Technology testing                            | 1                    | 1       | 1                      | 1         | 1                       | 1         |
| 5.5| Learning mechanism                            | 1                    | 1       | 1                      | 1         | 1                       | 1         |
| 6  | Internalization of technology                 | 0.908                | 0.556   | 0.906                  | 0.660     | 0.908                   | 0.531     |
| 6.1| Corporate information flow                    | 0.850                | 0.730   | 0.883                  | 0.719     | 0.892                   | 0.734     |
| 6.2| Data system and documentation                 | 0.916                | 0.784   | 0.920                  | 0.853     | 0.879                   | 0.654     |
| 6.3| Training approach                             | 0.877                | 0.780   | 0.778                  | 0.541     | 0.847                   | 0.735     |
| 7  | Technological capability                      | 0.953                | 0.680   | 0.958                  | 0.525     | 0.936                   | 0.619     |
| 7.1| Implementation of IT                          | 0.918                | 0.692   | 0.920                  | 0.659     | 0.888                   | 0.666     |
| 7.2| Implementation of advanced technology         | 0.955                | 0.680   | 0.960                  | 0.689     | 0.936                   | 0.620     |
| 7.3| Implementation of new technology              | 1                    | 1       | 1                      | 1         | 1                       | 1         |
| 7.4| Evaluation of technological capability        | 1                    | 1       | 1                      | 1         | 1                       | 1         |
| 7.5| Impact of technology capability               | 0.944                | 0.809   | 0.937                  | 0.790     | 0.948                   | 0.828     |
| 8  | Firm’s performance                            | 0.906                | 0.582   | 0.896                  | 0.591     | 0.918                   | 0.618     |
| 8.1| Market share                                  | 0.916                | 0.732   | 0.893                  | 0.678     | 0.927                   | 0.760     |
| 8.2| Quality/project performance                  | 0.831                | 0.631   | 0.828                  | 0.707     | 0.837                   | 0.652     |

All the path coefficients of the SEM framework are nonzero with a 90% confidence level. Thus, the coefficients have provided meaningful implications that significant influences exist from observed variables to latent variables.
### Table 4. Contractors’ Path for Technology Management Capability

| Path                        | All          | Large         | Medium        |
|-----------------------------|--------------|---------------|---------------|
| Latent                      | Observed     | Coeff.        | R²            | Coeff.        | R²            |
| Business Environment        | Firm’s Strategy | 0.081         | 0.007         | 0.247         | 0.061         | 0.199         | 0.04         |
| Firm’s Strategy             | Technological capability development | 0.092         | 0.008         | 0.336         | 0.113         | -0.19         | 0.036        |
| Technological capability development | Exploration of technology | 0.694         | 0.481         | 0.431         | 0.186         | 0.661         | 0.436        |
| Exploration of technology   | Acquisition of technology | 0.679         | 0.460         | 0.491         | 0.241         | 0.478         | 0.228        |
| Acquisition of technology   | Internalization of technology | 0.790         | 0.624         | 0.746         | 0.557         | 0.622         | 0.387        |
| Internalization of technology | Technology capability | 0.493         | 0.243         | 0.299         | 0.09          | 0.538         | 0.290        |
| Technology capability       | Firm’s performance | 0.348         | 0.187         | 0.367         | 0.146         | 0.357         | 0.251        |
| Firm’s strategy             | Firm’s performance | 0.261         | 0.187         | 0.075         | 0.146         | 0.447         | 0.251        |

The results of show three different path of technology capability development, as shown in the following figures.

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**Figure 4.** Technology Management Capability Development Path for contractors in Indonesia.

In general, despite having a strategic plan for achieving company performance goals and assuming that technological capability is important, contractors have yet to integrate it into the company's strategic plan. Adoption of technology will only be carried out if they are confronted with conditions where the technology capabilities of the contractor owned at that time are considered to be inadequate to complete construction projects. This is done because contractors in Indonesia generally still face limited resources in developing technological capabilities, so that the adoption of technology also tends to be outdated and low-cost technology. Therefore, even without certain strategic planning, the contractor in general can carry out the stages in adopting the technology quite well, both in terms of exploration, acquisition, and internalization of technology, so as to increase technological capabilities and achieve company performance targets.
Meanwhile, large contractors have generally integrated technology development plans into the company’s strategic planning. Adoption of technology is carried out on a variety of technologies needed in accordance with the latest developments, as long as company resources are sufficient for it. To support this adoption process, large contractors have sought it through its internal R&D and training units. In this way, large contractors can carry out the stages of technology development capacity development through exploration, acquisition, and internalization as well, which is reflected in the increase in technology capability and achievement of the company’s performance targets.
For medium-sized contractors in Indonesia, the use of technology is still considered a burden rather than a potential main asset of the company. So that in its strategic planning, these middle contractors have not yet included elements of technological development. A technology will only be adopted if the project conditions require the use of the technology. Although at a lower stage than the large contractors, the middle contractor also claimed to carry out the stages of adoption, exploration, acquisition and internalization of technology.

7. Conclusion
In studying contractors’ strategy in terms of technology management capability, factor analysis was used to identify different paths of development. Although still very limited, this model is not only able to help identifying different paths of technological development capabilities, but also provides an opportunity for users to understand how contractors respond to the role and influence of various variables in technology capacity development. Contractors seem to agree on the general path of technology capability development. However, they have different opinion when it comes to considering factors that would influence the development of technology management capability. The majority of large contractor acknowledge that they already have drawn up a corporate strategic plan and considered technology aspect into it. On the other hand, despite having no formalized strategic plan, medium contractors' interest in adopting the technology remain high.

8. Acknowledgments
Authors wishing to acknowledge the support and assistance from Indonesia Construction Service Development Board and the Ministry of Public Works and Public Housing, Republic of Indonesia.

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