Evaluation of Technology in Construction

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1. INTRODUCTION

1.1 Background

Leading construction companies in Japan have their own research centers, and they are investing 0.8 - 1.1 percent of their net sales on R&D (Research & Development). This number may be greater than the investment by construction companies in the United States, but far smaller than the investment by electrical manufacturing companies both in the United States and in Japan. Now we have following questions:

1. How much should construction companies spend on R&D?
2. How can the effectiveness of the investment on R&D be measured?

To answer the above questions, we need to know the proper evaluation method of technology. To measure or to estimate benefits and risks from the technology is the important factor to decide the amount of the investment on R&D and to judge the effectiveness of the investment on R&D.

Management of technology is one of the thrust areas of CIFE, in which several projects are going on including following two:
1. Using technology to gain competitive advantages in construction.

2. Barriers to integrated facility engineering.

Understanding the proper evaluation method of technology is also very useful in order to carry out the above projects effectively. Competitive advantages are one of the benefits from technologies, and understanding the benefits from the technology will help to remove the barriers.

1.2 Purpose of This Study

The purpose of this study is to find out the proper way to evaluate technology and to evaluate research and development projects, through which new technology is created.

1.3 Study Plan

First, papers concerning technology in construction, management of R&D, and R&D project selection were reviewed. Then, the proper ways to evaluate technology were discussed.
2. GROUPING OF TECHNOLOGY

It is said that different technologies should be evaluated with different ways. Let us discuss with examples of construction technology. One of the examples is the base isolation system, which is the effective system to escape from damages due to earthquakes. Another example of construction technology is the painting robot, which can reduce man-hours for painting work. Profitability is an important factor for both the base isolation system and the painting robot. Productivity is a very important factor for the robot, but not so important for the base isolation system. The base isolation system is the technology for design and the painting robot is the technology for process. Since these two technologies have different purposes, different criteria for evaluation should be prepared.

In this study, technologies which should be evaluated with similar criteria were grouped into the following three:

1. Basic technology
2. Technology for design
3. Technology for process

The basic technology is a result of research activities. The technology for design is a result of product development, and the technology for process is a result of process development. Therefore the activities to get technologies
can be grouped as follows:
1. Research
2. Product development
3. Process development

Some technologies may have characteristics of both the product development and the process development. CAD is a technology to improve the productivity of design. In this sense, CAD is the technology for process. But the graphic ability of the CAD can be used for presentation tools in marketing activities. In this sense, CAD itself is a new product and it can be considered as the technology for product.

3. ROLE OF TECHNOLOGY IN CONSTRUCTION INDUSTRY

Technology will bring benefits when it is used properly. Tatum(1) indicated four potential strategies for using advanced construction technology to gain competitive advantages. Those are 1. technology-based market and product expansion, 2. cost leadership based on new process technology, 3. differential technical capability, and 4. technology-based specialization.

Another potential strategy is establishment of reliable relationship to an owner with technology-based services. Construction companies will get a project either through a
competitive bid or direct designation from an owner. For instance, during a year from April 1987 to March 1988, Taisei corporation received orders of about 8.6 billion dollars. Projects of 3.4 billion dollars were obtained through competitive bid, and projects of 5.2 billion dollars were received without competitive bidding. Records of high quality works or completion of projects without delay may lead the owner to order his project to that company. The owner also order his project often to those who can be relied on because they can offer proper technology-based services. It is very favorable for construction companies to get jobs without competitive bidding.

Technology for the control of alkali aggregate reaction in concrete was useful to get reliance from owners. More than ten years ago, it was considered that there was no alkali reactive aggregate in Japan. But when some deterioration of concrete structures due to the alkali aggregate reaction were found in Japan, owners who wanted to have safe buildings from the damages due to the reaction ordered their buildings to the construction company that could offer the proper program to avoid the alkali aggregate reaction. These programs could be established through research activities in the company. This strategy is effective for the projects whose owners are more interested in a trouble free facility than are made less costly by a new technology. There are many such owners. Since the life period of construction
products is usually very long, this type of strategy may be more important for the construction industry than for manufacturing industry.

Strategy has important role not only to use technology but also to create new technology. There should be many different possible strategies. Preparation of menu for strategies will be a future work.

The research and development in own company is not the only means to obtain technology. Tatum(1) indicated potential strategies for obtaining advanced construction technology as follows: 1. persistent process improvement, 2. project-driven technology development, 3. internal construction R&D, 4. interaction with lead supplier, 5. forward technical integration, 6. backward technical integration, 7. brokering for technology leadership, and 8. brokering for technology followership.

Balderston et al. (2, pp.119-121) discussed four R&D strategies. Those are: 1. offensive, 2. defensive, 3. licensing, and 4. acquisition. They discussed as follows:

When a market is open to preemptive first moves or when the competitor needs a long lead time in order to catch up, then an offensive strategy is indicated... The offensive strategy has some high potential payoffs, but the risks are substantial. For this reason many firms prefer a defensive approach to R&D strategy... There are situations where the cost of research and development may be prohibitive. This normally occurs in a technology that is not mainline to the firm... In this case, this firm may choose to purchase a license from
another firm... An extended version of the licensing approach is the acquisition strategy. Some firms faced with a need to develop a new technology will purchase a firm that has developed that capability.

4. OBSTACLES FOR ADOPTION OF TECHNOLOGY IN CONSTRUCTION

The productivity in the manufacturing industry has increased tremendously after the world war II by adopting new technologies. On the contrary it is said that the productivity in the construction industry has decreased during the same period. Why is the adoption of new technologies so slow in the construction industry?

Nam and Tatum(3) listed major characteristics of constructed products and resulting limitations of construction technology. The characteristics of constructed products are 1. immobility, 2. complexity, 3. durability, 4. costliness, and 5. high degree of social responsibility. The most important factor for resulting limitations of technology is the immobility. The immobility of constructed products prevents their whole production in the factory environment. Technological consequences of site operation for construction are 1. limitation on mass production, 2. regionalism, and 3. seasonalness. Individual taste of owners and handling of bulky and heavy materials are barriers for mass production.
5. EVALUATION OF TECHNOLOGY

5.1 Significance of Evaluation

Evaluation has to be done at several stages of R&D process, from idea generation to application of the technology. The earlier the stage is, the more difficult to evaluate the technology because risks and uncertainty prevent adequate information for evaluation. In this paper, evaluation methods of research projects are discussed because the same method can be employed to evaluate developed technology. In the later case, risks and uncertainty become a less important factor.

Since one of the main purposes of R&D activities is getting competitive advantages for the corporation in future, research projects have to fit into overall corporate objectives. When the project comes from the top management, it will be suited to the corporate strategy. When the project is proposed by research engineers, the top management has to let the research engineers know the corporate objectives well. To fit the bottom up projects into corporate strategy, close communication between the top management and the research engineers about corporate objectives is necessary. Setting a clear evaluation method for research projects is one of the most effective communication tools. A good evaluation method will tell the
research engineers what the top management wants to have.

Balderston et al. (2,p.138) also indicated as follows:

The likelihood of a project being well suited to the corporate objectives is enhanced by a well-designed project selection and evaluation system... The very existence of these systems indicates that the corporate support is an issue. In addition, the explicit inclusion of strategic issues and corporate objectives into the system increases the likelihood that projects selected will develop in coherence with the overall corporate objectives. Even a rather crudely designed system will force the project proposers to explicitly consider the corporate objectives. The development of a systematic method to select and evaluate projects is an imperative.

Sometimes, it is said that a severe evaluation of a research project may prevent the generation of good ideas and may reduce the motivation of the research engineers. But proper evaluation is necessary for selecting the best sets of research projects and making suitable R&D resource allocations. Proper evaluation of research projects will bring higher productivity in R&D, and will make the future of the company promising.

5.2 Difficulties in Evaluation

To evaluate research projects properly is not an easy task because usually sufficient information for evaluation cannot be obtained. Factors that make evaluation difficult are: 1. risk and uncertainty, 2. multiple and often interrelated criteria, 3. interrelationships of projects, and 4. nonmonetary aspects such as balance in the R and D program.
Baker and Freeland(4) discuss the requirements for good R&D decision models and develop a list of performance criteria and characteristics amended from Souder’s work. This list is shown in Table 1.

Too sophisticated models for evaluation may not be useful because managers will not employ them. Balderston et al. (2,p.44) indicated this as follows:

Most managers and executives like to make decisions; many think decision making is the essence of their jobs. The authority to make decisions and see them carried out frequently means power. Many are reluctant to give up that power. They like to think that unique experience and intuition that they bring to bear on decisions uniquely qualify them to continue to hold their jobs.

To evaluate research projects properly, we need a system which supports the decision maker rather than models with which the decision maker is replaced.

5.3 Evaluation Method

5.3.1 Basic Steps

Many literature associated with quantitative models of the R&D project selection and resource allocation decision have been published. Establishment of basic steps in evaluation will be helpful in order to understand how each model is
TABLE 1 Criteria and Their Characteristics for Evaluation of R&D Decision Models from Baker and Freeland (4)

(1) Realism Criterion Characteristics

Model includes: Multiple objectives, Multiple constraints, Market risk parameter, Technical risk parameter, Manpower limits parameter, Facility limits parameter, Budget limits parameter, Premises uncertainty parameter

(2) Capability Criterion Characteristics

Model performs: Multiple time period analysis, Optimization analysis, Simulation analysis, Scheduling analysis

(3) Flexibility Criterion Characteristics

Model applicable to: Applied projects, Basic projects, Priority decisions, Termination decisions, Budget allocation applications, Project funding applications

(4) Use Criterion Characteristics

Model is characterized by: Familiar variables, Discrete variables, Computer not needed, Special persons not needed, Special interpretation not needed, Low amount of data needed, Easily obtainable

(5) Cost Criterion Characteristics

Model has: Low set-up costs, Low personnel costs, Low computer time, Low data collection costs

(6) Additional Criteria

Model considers: Competitor efforts, "Strategic need", Project dependencies (value, resources), Updating data, "Flag" for potential problem areas
concerned with the evaluation process. It becomes clear that typical evaluation systems have following steps:

1. Setting criteria - The evaluation process begins with specification of criteria for the evaluation. Some evaluation methods employ only one criterion such as profitability. But usually other criteria, such as fits into overall objectives and strategy, cannot be ignored, and multiple criteria are employed. These criteria must be related to the strategy of the company. When the company aims for cost leadership, productivity becomes an important criterion. More discussion on criteria will be made in 5.4.

2. Preparing data - After a set of criteria are determined, related data will be collected. In the economic index models, many data, such as "k"-th year's profit of project"j" and R&D cost for "k"-th year, are required. In the scoring models only few data will be required.

3. Integrating data - In this process, values are calculated with the data obtained above and the project is scored on each criterion. One of the economical index models calculates the figure of merit by

   \[ rdp(T+B)E / \text{total investment}, \]

where "r" is the probability of research success, "d" is the probability of development success, "p" is the probability of market success, "T" and "B" are indexes of technical and
business merit, and "E" is the present value of earnings from the project. In scoring models, values, such as 1 to 5 (1 is poor and 5 is excellent), may be assigned without mathematical formula.

4. Overall rating - In this process, each project is rated. When single criterion is employed, the project can be rated from the assigned value directly. The economic index model is usually the case. In multiple criteria models, the criteria will be weighted for relative importance and transformation rules developed. One of the simplest procedures is to develop a weighted sum for each objective composed of the sum of the weighted criterion scores.

5. Making decision with algorithm - Measurement of benefits from the projects is finished in the overall rating process. This process is for selection of projects and optimization of resource allocation. This algorithm is usually expressed by mathematical models, and many mathematical models for project selection were proposed.

5.3.2 Scoring Model

The scoring model is one of the most widely used models for R&D project selection. In this model, each candidate project is scored on each criterion, using an appropriate scoring scale (corresponding to the basic step 3). This result in a
set of criterion scores. In most cases each criterion is weighted relative to its perceived importance, resulting in a set of criterion weights. These scores and weights are combined typically according to the following formula (basic step 4) (5):

\[ T_i = (W_1 \times S_{i1}) + (W_2 \times S_{i2}) + \ldots, \]

where "Ti" is the total weighted score for project "i", "Wj" is the criterion weight for the "j"-th criterion, and "Sij" is the criterion score for the "i"-th project on the "j"-th criterion.

One of the advantages of the scoring models is that they can express corporate objective clearly by selecting criteria carefully. Steele(6,p.23) discussed as follows:

The scoring approach has a number of attractive features, of which two are dominant. First, it lends itself to "home-grown" development. Any R&D organization can, without undue effort, develop the set of criteria, the scales, and the weights that its management believes are most appropriate for local circumstances and that fit the predilections of local management regarding degree of complexity and elaborateness... One important benefit derives from the process of internal development. It forces management to think carefully about the criteria that should be used in evaluating R&D programs. It then provides a language for all members of the organization to use in evaluating program. These scoring techniques are probably best described as systematic rather than objective, but they can provide a structure for identifying sources of disagreement and thus help make management discussions more productive.

Krawiec(7,p.22) discussed the advantages of the scoring models as follows:

The scoring methods demonstrate the following
comparative advantages:
1. They are the only methods specifically designed to incorporate noneconomic criteria.
2. They use input data in the form of subjective estimates provided by knowledgeable people as well as in the form of point or interval statistical estimates.
3. They use subjective "guesses" overtly where the other methods generally require a more costly and sophisticated quantitative form of the same "guess."
4. The subjective probability assessment can be built into the conceptual and analytical framework of the scoring method to produce an efficient portfolio of R&D projects.
5. The scoring methods produce results that are, on an average, 90 percent rank-order consistent with economic and constrained methods.

Usually, sophisticated formulae are not employed to score on criteria. But for reasonable scoring, utilization of some formulae will be useful. One of the examples of scoring with formulae is the project appraisal methodology by the Division of Fossil Fuel Utilization, Department of Energy, which is presented by Silverman(8). They employed three criteria - energy/cost ratio, consumer/cost ratio, and effects and impact score. Weighted energy/cost ratio of project "i" at funding level "j" (ECij) will be driven from a number of data such as coal used by technology "i" in market segment "p" in year "t" and efficiency improvement in oil or gas use by technology "i" in market segment "p" in year "t". Consumer savings/cost ratio of project "i" at funding level "j" (CSij) comes from data such as capital cost of technology "i" in market segment "p" and cumulative units installed for project "i" at funding level "j" in market segment "p" in period "t". The effects and impact score (EISi) is sum of data such as aggregate impact on air,
water, land, noise, and other environmental media and aggregate social effects. Then the overall rating is measured by summing the value for each criterion. In this methodology, value of the effects and impact score (EISi) is weighted by 0.5 in the overall rating while the other scores are weighted by 1.0. Lastly the total weighted score is multiplied by data tolerance of project "i" at funding level "j", and then the overall rating for project "i" at funding level "j" can be obtained.

5.3.3 Economical Index Model (9)

Usually the return of the investment on R&D is the most important factor to evaluate R&D projects. A large variety of index models have been developed. The economical index models are concerned with the basic step 3.

One of the popular economical indexes is a cost-benefit ratio. It has the general form

\[ I = \frac{R}{C} \]

where "I" is the index, "R" is the total return from the project, and "C" is the total project cost. "R" may be estimated from 1. present value of profit of product "j" in "k"-th year, 2. contribution factor of research project "i" related to product "j", 3. present value of cost of project "i" in "k"-th year, 4. the probability of research success, 5. the probability of development success, and 6. the
probability of market success.

Another popular index is internal rate of return (IRR). The IRR directly relates to the cost-benefit ratio, but projects which have the same cost-benefit ratio would not have the same value of IRR. When the project generate profit in shorter period, the IRR is greater than the IRR of the project that generate profit in longer period and has the same cost-benefit ratio. Since R&D is one of the objectives for investment, the IRR is useful to compare the effectiveness of the investment on R&D with the effectiveness of other possible investment.

A proper economical index model will be helpful to answer the first question, "How much should we spend on R&D?" One possible answer is to accept all projects which the IRR is greater than the cost of capital. The budget is then the sum of all approved projects. However difficulty in getting real profit of each project, risk and uncertainty makes decision makers reluctant to employ this approach.

Since the economical index models include a method to score projects on economical criterion, they can use in combination with the scoring models.
5.3.4 Project Selection / Resource Allocation Model

This model provides algorithm for the resource allocation, and it is sometimes called a portfolio model. And this model is for the basic step 5. One simple algorithm for selection is as follows (5, p. 121):

1. Rank the decision alternatives in decreasing order of their value. Alternatives with the same ranking may be listed in any order.
2. Select the highest-ranked alternative. If ties exist, select the highest ranked alternative with the lowest cost. Remove this selected alternative from the list of candidates and place it in the funded alternatives.
3. Subtract the cost of this selected alternative from the available funds. If the available funds are inadequate for this selected alternative, then replace it in the candidate list and select the next best alternative that can be funded with the available funds.
4. Iterate steps 2 and 3 until the available funds or the budget is exhausted. If funds remain after funding all the alternatives, or if the remaining alternatives each cost more than the available funds, then these funds are simply left over.

A large number of mathematical models, which provide more sophisticated algorithm, have been developed. Souder (5, p. 77) explained the portfolio models as follows:

The models differ interims of the types of input data used, the nature of the decision problem, what the decision maker wishes to maximize, the riskness of the situation, and other aspects. In general, the portfolio problem may be represented mathematically as follows:

Maximize: \( Z = \sum p \cdot f(X_j) \)
Subject to: \( g_i(X_j) \leq b_i \)
\( c_i X_j \leq B \),

where \( f(X_j) \) is the objective function, e.g., maximize profits, \( p \) is a parameter for risk, \( 0 \leq p \leq 1 \), \( g_i(X_j) = b_i \) is a set of resource constraints, \( c_i \) is a unit resource cost, and \( B \) is a dollar budget. Linear, nonlinear, and other mathematical programming techniques are thus often use to find solutions to portfolio problems.
To use the mathematical model effectively, benefits of several versions of the project with different funding levels should be prepared. Otherwise in the mathematical model each project is either rejected completely or selected and funded at some pre-budgeted level.

When the number of projects and the number of versions of the project increase, a large computer memory and a long computing time will be inevitable. The mathematical model using such as the linear programing technique will bring the optimal solution precisely, but in many cases, a sub-optimal solution is preferable if the computer memory and running time can be reduced dramatically. One of the example models that need less computer time is the decomposed heuristic proposed by Mandakovic and Souder(10,p.1262&pp.1264-5). This model has following algorithm:

Instead considering each version as an individual project, our decomposed procedure assesses all the versions of each project... First, the superordinate (R&D manager) sends the initial availability of resources to the subordinates (Project managers). Then, the subordinate calculates the effective gradient for each of his versions, and chooses the one with the highest value. The highest value is sent to the superordinate. (At this point the subordinate might be allowed to include versions that he had not included before, so that he can get a better chance for funding at the actual level of availability of resources.) The superordinate then selects the highest value among the ones sent by the subordinates. The superordinate includes the winning project in the portfolio, and calculates the new availability of resources, sending back this information to each project manager. The subordinate again calculates the gradients for each remaining version, etc. This process terminates when the availability of resources does not permit new
projects in the portfolio.

5.4 Criteria for Evaluation

Setting criteria and weighting them properly are the main factor to make a proper evaluation. Any good evaluation models cannot bring sufficient results if the criteria are not specified properly. In this section, typical criteria for research, product development and process development are discussed.

Criteria for evaluation of R&D projects can be grouped into following five: 1. cost, 2. benefits, 3. risks, 4. suitability, and 5. others. The cost includes research and development cost, research and development time, and capital investment required. The benefit includes profitability, size of potential market, and patent status. The risk includes likelihood of technical success, and market risk during development period. The suitability includes capability of available skills, relationship with existing markets, and balance between development and research.

Becker(11) introduced typical criteria in the project selection checklists developed by an Industrial Research Institute Committee as follows:

A set of project selection criteria was developed by the subcommittee from the criteria listed by B.V.Dean (AMA Research Study, 89). The list was updated to reflect regulatory and legal trends into a set of
thirty-six criteria as shown in Table 2. The subcommittee then polled itself to determine the criteria for selection for the different types of technical activity and to determine whether the source of inputs varied widely for different activities. The criteria were found to fall into three checklists: 1) those for selection of research projects; 2) those for selection of product development projects; and 3) those for selection of process development projects.

There were nine major criteria in selection of a research project. They were:
1. Fits into overall objectives and strategy
2. Cost
3. Likelihood of technical success
4. Size of potential market
5. Patent status
6. Availability of R/D resources
7. Market trend and growth
8. Development time
9. Capability of available skills

There were thirteen major criteria in selection of product development projects in the survey. They were:
1. Cost
2. Likelihood of technical success
3. Profitability
4. Size of potential market
5. Development time
6. Fits into overall objectives and strategy
7. Capability to market product
8. Market trend and growth
9. Capability of manufacturing product
10. Market share
11. Patent status
12. Potential product liability
13. Capital investment required

There were eleven major criteria in selection of process development projects. They were:
1. Likelihood of technical success
2. Facility and equipment requirement
3. Cost
4. Capital investment required
5. Fits into overall objectives and strategy
6. Development time
7. Profitability
8. Cost savings
9. Capability of manufacturing product
10. Rate of return on investment
11. Regulatory clearance
When attention is paid to only the criteria related to the benefits from the projects, following things can be pointed out:

1. "Fits into overall objectives and strategy" appears first in the major criterion in selection of the research project, which mean this criterion is very important for the evaluation of the research project. This criterion also appears in the major criteria for both the process and the product development projects, but it is not at the first place.

2. "Profitability" is very important in selection of the product development project (the third place), important in selection of the process development project (the seventh place), and less important in the research (not appear).

3. Criteria related productivity, such as "cost savings," only appear in the set for the process development project. These things are summarized in Table 3.

Benefit related criteria for the evaluation of research are:

1. fits into overall objectives and strategy, 4. size of potential market, and 5. patent status. It is difficult to evaluate research projects on these criteria with quantitative method. The sophisticated methods should be used only for the evaluation of the development projects. Sometimes, it is said that the track record of the person proposing the research project is regarded as the best indicator of evaluation.
TABLE 2 Project Selection Criteria
from Becker (11)

<table>
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<tr>
<th>Corporate objectives</th>
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<tr>
<td>Fits into overall objectives and strategy</td>
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<td>Corporate image</td>
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<td><strong>Marketing and Distribution</strong></td>
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<td>Size of potential market</td>
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<td>Capability to market product</td>
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<td>Market trend and growth</td>
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<td>Customer acceptance</td>
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<td>Relationship with existing markets</td>
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<td>Market share</td>
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<td>Market risk during development period</td>
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<td>Pricing trend, proprietary problem, geographical extent, and effect on existing products (each)</td>
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<td>Complete product line</td>
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<td>Quality improvement</td>
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<td>Timing of introduction of new product</td>
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<td>Expected product sales life</td>
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<td><strong>Manufacturing</strong></td>
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<td>Cost savings</td>
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<td>Capability of manufacturing product</td>
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<td>Facility and equipment requirement</td>
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<td>Availability of raw material</td>
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<td>Manufacturing safety</td>
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<td><strong>Research and Development</strong></td>
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<td>Likelihood of technical success</td>
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<td>Cost</td>
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<td>Development time</td>
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<td>Capability of available skills</td>
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<td>Availability of R/D resources</td>
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<td>Availability of R/D facilities</td>
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<td>Patent status</td>
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<td>Compatibility with other projects</td>
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<td><strong>Regulatory and Legal Factors</strong></td>
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<td>Potential product liability</td>
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<td>Capital investment required</td>
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<td>Annual (or unit) cost</td>
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<td>Rate of return on investment</td>
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<td>Activities</td>
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<td>Productivity</td>
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1: Important
2: Very important
5.5 Productivity as Criteria for Evaluation (12) (13)

Little increase or even decrease of productivity in construction is a big problem. The R&D in construction is expected to improve this situation. The main role to improve the productivity in construction is on the process development.

Profitability can be a dominant criterion for the product development, but for process development, criteria other than productivity are also important and cannot be ignored. Here, the evaluation of the process development project in construction which intended to improve the productivity is discussed.

5.5.1 Factors Affecting Productivity

Following factors may affect the productivity in construction.

1. Characteristics of the industry - inordinate fragmentation

2. Characteristics of the common projects - immobility, little repetition, bulky and heavy materials

3. Characteristics of the specific project - geographical location, project size, project schedule, expected construction activity in the project area, climate, special site condition
4. Labor - organized labor, experience of crew or supervisor, overtime, motivation

5. Management - demotivation of workers, a little use of modern management system, safety, types of contracts

6. Technology

7. Others

The first three factors shown above are difficult to change. Labor, management and technology can be changed to improve productivity. Many studies are conducted on the influence of labor and management, but here we concentrate on technology as factors of the productivity.

5.5.2 Technology as Factors of Productivity

One of the most popular definition of the productivity is a comparison of the output of the production process to the corresponding input (i.e., Productivity = Output/Input). According to this definition, productivity improvement by technology can be measured. But at the same time, other factors such as the cost for the research project and the capital investment required for adoption of the technology have to be considered. To increase the output of construction works, use of a large machine may be effective. But no one will use a too large machine if the price of the machine can be compensated by the capability of the machine. When the productivity of the technology is evaluated, one
must be confirm that the technology has the possibility to become the best set of technology from both technical and economical aspects. Koch and Fred(14) analyzed productivity and technology change in construction. This analysis is useful to evaluate the technology with which productivity will be improved. Here their work is quoted:

Salter was probably the first person to make a concerted effort to measure and then divide the change in factor productivity into its component parts. Measures of efficiency, returns to scale, factor bias, and elasticity of factor substitution are the four standardly cited characteristics of a technology. The nature of the technology itself, as depicted by these characteristics, and relative factor prices are commonly recognized as the primary determinants of factor productivity. In combination, these factors determine the best-practice (least-cost) technique for any particular period. Movements over time of the best-practice technique, then, represent technology change, and it is this which Salter tried to decompose. Assuming constant returns to scale over the range of capacity outputs being considered he defined quantitative measures for the remaining technological characteristics.

Based on Salter’s work and basic economic concepts, then, a schematic representation of dividing technology change into its component parts was developed as given in Fig.1. Movement of the best-practice technical package from the resource mix of point A in period n to that of point D in period n+1 represents a change in technology characterized, for example, by increasing efficiency (A to B), labor-saving bias (B to C), and substitution of capital for labor (C to D), with return to scale assumed constant. Knowing the resource mixes at points A, C, and D, which are real technical packages, and recognizing the equality of the capital-labor ratios at points A and B and cost equality at point B and C, the contributions of each of these components can be quantified by means of straightforward mathematical computations. It might be noted that cost reductions are associated with the efficiency and substitution shifts and might be perceived as motivations behind the changes but not with the bias shift, the motivation for which remains somewhat unclear.
Note: Constant returns to scale are assumed.

A best-practice technical package at the prices of period n, given \( T_n \) as the production isoquant

B theoretical technical package defined to separate the effects of efficiency and bias; its capital/labor ratio is the same as that of A, while its cost is the same as that of C

C best-practice technical package at the prices of period n, given \( T_{n+1} \) as the production isoquant, or both \( T_n \) and \( T_{n+1} \)

D best-practice technical package at the prices of period n+1, given \( T_{n+1} \) as the production isoquant, or both \( T_n \) and \( T_{n+1} \)

Fig.1 Schematic Representation of Dividing Technology Change, Represented by Movements Over Time of Best-Practice Techniques, into Its Component Parts from Koch and Moavenzadeh (14)
Development of this figure for the case of highway construction in the United States at various points in time is thus central to the study at hand....

The role of technology in the productivity of highway construction over the years in the United States appears indeed to have been a significant one. Highways can be constructed today using considerably less labor and even less capital than was possible in the second and third decades of this century.

It should be noted that reduction of capital requirements is a key factor for adoption of new technology. In the manufacturing industry, mass production could reduce the cost of machines for one product. The difference of each product is one of the main cause of the slow adoption of new technology in construction. Since each product in highway construction (highway) is very similar compared with products in building construction, adoption rate of new technology has been high in the highway construction but low in the building construction. Today some automation systems in the manufacturing industry become so progressed that many different types of products can be produced through the same system. Utilization of computer technology enabled such a flexible system. The flexible technology, which can be adopted to many projects, will be promising to improve productivity in construction.

Areas that will offer high potential for productivity improvement through research are pointed out by the University of Texas researchers(12,p.29) as follows:

1. piping, 2. installation of mechanical equipment, 3. electrical work, 4. structure, 5. vessels, 6. heating, ventilating and air conditioning, 7. installation of
special equipment, and 8. instrumentation

And the promising means for improving productivity are also pointed out (13, p.113 & pp.436-486) as follows: 1. prefabrication, 2. preassembly, 3. modularization, 4. computers - CAD, manufacturing information system, 5. robotics, 6. automation, and 7. knowledge-based expert system.

6. CONCLUSION

This paper discusses the evaluation of technology and the evaluation of research projects. Some important points are:

When technology is evaluated, activities to create the technology should be grouped into 1. research, 2. product development, and 3. process development. Technologies in each group will be evaluated with similar criteria.

A well-designed project selection and evaluation system is necessary to help research engineers propose projects that are well suited to the corporate objectives.

The basic steps of evaluation and selection of research projects are: 1. setting criteria, 2. preparing data, 3. integrating data, 4. overall rating, and 5. making decision with algorithm.
To evaluate research projects, fitting into corporate strategy is a very important criterion. To evaluate product development projects, profitability is very important, and fitting into strategy is also important. To evaluate process development projects, productivity is very important, and profitability and fitting into strategy are also important criteria.

When technology for productivity improvement is evaluated, it should be confirmed that the technology will be the best-practice (least-cost) technique.

In this short research period, the proper model could not be defined. The proper model should include proper way to get data with which index can be calculated. Establishment of a proper economic model for R&D in construction will remain for future works.

7. REFERENCES


