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Technology assessment for portfolio managers

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ABSTRACT

In 2008 the CFA Institute, a global association of investment professionals, added a new topic to its Professional Development Program: "How to judge the technological strength and potential of companies" This offering reflects the growing importance of technological considerations in investment decisions. The offering is rooted in a comprehensive procedure for a technology due diligence exercise. The procedure relies on the recent advances in the management of technology (MOT), and particularly on the *functionality grid*, a key construct in the theory of technology. The procedure is summarized in a one-page *Technology Assessment Template* that allows portfolio managers to perform a quick individual assessment. This article describes the *Template* and offers brief guidelines as to its use.

1. Introduction

Due to the growing technification of society, portfolio managers face an increasingly difficult task in making sound investment decisions. Not only do portfolio managers have to consider the relative attractiveness of new technologies such as nano-tech, bio-tech, cellulosic ethanol, wind power, meaning–gleaning search engines, and industrial bacteria but they also have to assess a company's ability to tap into and benefit from the ever expanding technological frontier. In addition, managers have to grapple with mounting evidence of *technological impotence* within esteemed industrial icons like GM, Ford and Chrysler.

Modern portfolio managers find that in addition to the traditional elements of (i) doing the numbers, and (ii) scrutinizing management, they need to be able to assess the technological vitality and resilience of the companies.

In response to the need identified, the CFA Institute in 2008 added the theme *How to judge the technological strength and potential of companies* to the offerings on its *Professional Development Program*. The offering is positioned as *Technology Assessment for Portfolio Managers*. While the offering is based on an extensive procedure permitting a thorough technology due diligence exercise, it is also condensed into a basic assessment tool, a *Technology Assessment Template*. This article describes the development of the *Template* and offers brief guidelines as to its use.

2. Background

The origins of the *Technology Assessment Template* are to be found in the dot.com meltdown. This meltdown attracted much attention. It was the subject of an active research initiative conducted within the Master of Science in the Management of Technology (MS-MOT) program at the University of Minnesota. Graduate teams tracked the histories of newly quoted high-tech companies, and monitored their investment records. The teams followed the comments of investment professionals during the launch and correction phases.

The research showed that investment professionals had great difficulty in articulating the technological strength and potential of the companies they promoted. It was hard to describe, in simple terms, what the unique technological attributes of a company were. Professionals had little skill in locating and characterizing the *inherent potency* of the technologies involved. Consequently, professionals sometimes resorted to hype in their marketing efforts. When the crunch came, they had difficulty in rationally defending the valuation judgments.

These findings were discussed and analyzed within the wider investment community including the CFA Society of Minnesota. Further investigation revealed that major, technology-based, booms and slumps occur regularly every fifty years or so (Perez, 2002). Major slumps are interspersed with minor ones. Technological bubbles are not unknown in the investment community

In spite of this, the Candidate Book of Knowledge for the CFA qualification, the so-called CFA-BOK™, hardly dealt with technology at all (CFA Institute, 2001). Technological acumen and awareness was not a part of the portfolio manager's normal skill profile.

In 2004 Technoscan® Centre started work on technology assessment procedures for investment professionals. The Centre charts the technological frontier and acts as an advisor to the high-tech executives. The Director of the Centre, who formerly served as the Director of the Management of Technology Program at the University of Minnesota, was intimately involved in the dot.com research.

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In 2005, the CFA Society hosted a presentation to its members on "Technology Diagnostics for Investment Professionals". At this meeting participants voiced their requirements. They pointed to the need for an extremely simple tool that could be readily learnt and that could focus on the key criteria for technological strength and potential. They pointed to the need for a *Technology Assessment Template*.

Technoscan® Centre then set about developing and testing a simple *Template*. This was done in many settings ranging from academic workshops, in-company presentations, and investment conferences. In 2007 Technoscan® Centre reported an assessment procedure to the CFA Institute, and applied for it to be approved as educational material for the CFA. The procedure was audience tested, and in 2008 the CFA Institute included the material in its Professional Development Program.

3. Requirements for a template

Based on the discussions with investment professionals, the template had to fulfill five requirements. It had to be

- an addition to traditional evaluation procedures, not a replacement,
- simple enough to be readily understood by non-specialists,
- condensed—ideally formatted on to one page,
- adaptable—it had to be usable in a "quick assessment" mode lasting less than an hour as well as in a "technology due diligence" mode that may require a few days, and
- versatile in use, i.e., able to assess both written material as well as live interviews.

The requirements of simplicity and versatility were particularly challenging given the complexity of technological know-how.

Fortunately Technoscan® Centre could draw on the recent advances in the theory of technology. Over the previous few decades, technology theorists had developed a unique tool-kit called the Strategic Technology Analysis (STA). Based on a central format called the "functionality grid", it offered a set of frameworks to unify and simplify technological knowledge. The development of STA is fully documented elsewhere and will not be repeated here. (Gaynor, 1998; Clarke, 2004; Van Wyk, 2004).

In 2005, the International Association for Management of Technology (IAMOT) recognized its value by way of a Distinguished Achievement Award in the Management of Technology. It provided a convenient new pathway for the specialists to express themselves to a lay audience. To non-specialists it offered a non-threatening route towards technology edification.

4. Structure of the template

The compilers of the *Template* focused on the three important criteria. Technological strength and potential required

- a robust technological base,
- effective procedures for technological renewal, and
- technology-conversant management.

The first criterion deals with the technology *platform* of a company while the second and the third deal with *organizational* features. The basic structure of the Template is set out in Diagram 1. It identifies the indicators that can be used to judge the above criteria.

In its basic form the *Template* can be used as a lone standing tool by anybody who is technologically attentive. In this fashion it can be used in quick assessment mode. For a deeper evaluation, portfolio managers need more comprehensive instruction. And for penetrating probes, such as in due diligence studies, managers would need to become technologically sophisticated and edified. To support deeper probes, Technoscan® Centre has prepared a user's guide (Van Wyk, 2008).

Criterion	Indicator	Comment
Robust technological base	Key technologies have been identified and ranked	
	Technology base has a clear functional focus	
	Key technologies have high potency	
	Key technologies have a good future-fit	
Effective procedures for technological renewal	Procedures exist for exploring new technologies	
	Procedures exist for aligning strategy with technological opportunities	
Technology-conversant management	Technological knowledge is systematized	
	Technology outlook is formalized	

Diagram 1. Technology Assessment Template.

In the rest of this article we view each of the indicators in the *Template*. For each indicator, portfolio managers can enter an impressionistic comment in the third column of the *Template* to create a report card for the company.

5. Robust technological base

5.1. Key technologies have been identified and ranked

Modern companies have extensive technology platforms involving complex clusters of multiple technologies.

A complete review of the entire corporate technology base is therefore not possible; a selective approach must be used. In their interviews and review of corporate reports, portfolio managers should focus on "key" technologies—i.e., "the important few". Key technologies reflect the company's unique capabilities and distinguish the company from its competitors.

In the case of specialized companies such as Seagate, it is fairly easy for executives to identify key technologies. In the case of diversified companies, like GE and 3 M, it is a harder task. It may be necessary to repeat the exercise for each of the company's different businesses. However many diversified companies have unifying competencies that reflect the company's unique capabilities.

A typical list of key technologies contains approximately five to ten items. These technologies may reside in any of three areas

- product technologies,
- process technologies, and
- decision support technologies.

Portfolio managers should observe how the company identifies key technologies and differentiates among them. There are various approaches. One approach distinguishes between

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- emerging technologies,
- pivotal technologies, and
- mature technologies.

Emerging technologies are technologies that are in the first stages of development. Pivotal technologies are proven and play important catalytic roles. Mature technologies form the basis for products and processes that are well-established in the market place.

Another approach distinguishes between

- bankers and
- candidates.

Bankers are the technologies on which cash-cow products and processes are based; and candidates are the technologies that are expected to feature in the future.

If the company has gone through a formal exercise of identifying *core competencies,* these competencies will offer insight into the key technologies.

Next, portfolio managers should note whether and how these technologies are ranked in order of importance to the company. Portfolio managers should then be able to enter a personal judgment in the first row of the *Template*.

5.2. Technology base has a clear functional focus

Does the technology base clearly reflect the functional focus being claimed by the company? Functional focus is an important attribute. It indicates whether the technology base is in harmony with the company mission, and it helps to judge the technology potency—to be discussed more fully below.

To describe functional focus, some corporations use a narrative description. Most will refer to a system of classification, (e.g., Magee and De Weck, 2004). Portfolio managers can obtain a clear picture by using the functionality grid referred to earlier. The functionality grid relies on the realization that all industrial activity is based on nine core functionalities. These are illustrated in Diagram 2.

The grid is one of the most profound and creative theoretical formats of the twentieth century. It is based on the pioneering work of Ropohl (1979). As mentioned before, it forms the central construct of a set of frameworks that constitute a key tool-kit for MOT.

To illustrate the use of the grid we may refer to a company like Weyerhaeuser. Essentially it is in the business of making paper and carton. In terms of the grid, the company's process technology would be positioned as *matter processing* (MP). Product technology would have two entries. Paper used as print media reflects the functionality of *information storage* (IS) while carton used for packaging reflects the functionality of *matter storage* (MS).

Portfolio mangers should note whether the company has a clear view of its functionality profile. They can then write an impressionistic comment in row 2 of the *Template*.

Armed with this profile, portfolio managers can now focus on how well the company executes its fundamental functions.

5.3. Key technologies have high potency

Technological potency refers to the inherent advantage residing in a technology. It is a subtle but most important attribute in judging technological strength and potential. Its absence signals *technological impotence*—a disturbing malady afflicting a number of the US industrial icons today.

Potency is reflected in excellent technology performance metrics (TPMs) covering attributes such as efficiency, throughput, density or accuracy. Normally it is due to a unique characteristic such as a new principle of operation, better structure, change in size, or a new material. Frequently it emerges from a cluster of contributing attributes.

Diagram 3 offers a guide to identify the locus of the technological potency (Van Wyk, 2004). Items 3 and 6 can be expressed in terms of simple technology performance metrics (TPMs). Item 4 can be partially dealt with in terms of metrics, and partially qualitative description. Items 2, 5, and 7 call for qualitative description.

The present debate on biofuels provides a useful example of relative technological potencies. We focus on Item 3 and particularly on energy efficiency. As TPM we use the amount of energy that a bio-fuel yields in relation to one unit of fossil fuel used in the making thereof.

Using this measure it is claimed that corn-based ethanol yields 1.3 units of energy per unit of fossil fuel used. Cane-based ethanol yields 8 units while cellulosic ethanol, depending on circumstance, could yield between 2 and 36 units (Bourne, 2007).

		Action		
		Process	Transport	Store
Output	Matter (M)	Transforming substances	Moving substances	Keeping substances
	Energy (E)	Generating energy	Distributing energy	Holding energy
	Information (I)	Composing messages	Sending messages	Saving messages

Van Wyk, Rias J: *Technology -A Unifying Code*, 2004, Stage Media Group, Cape Town, p. 34
Based on: Ropohl, Gunter: *Eine Systemtheorie derTechnik*, 1979, Carl Hanser Verlag, Munich and Vienna, p. 178.

Diagram 2. Functionality grid.

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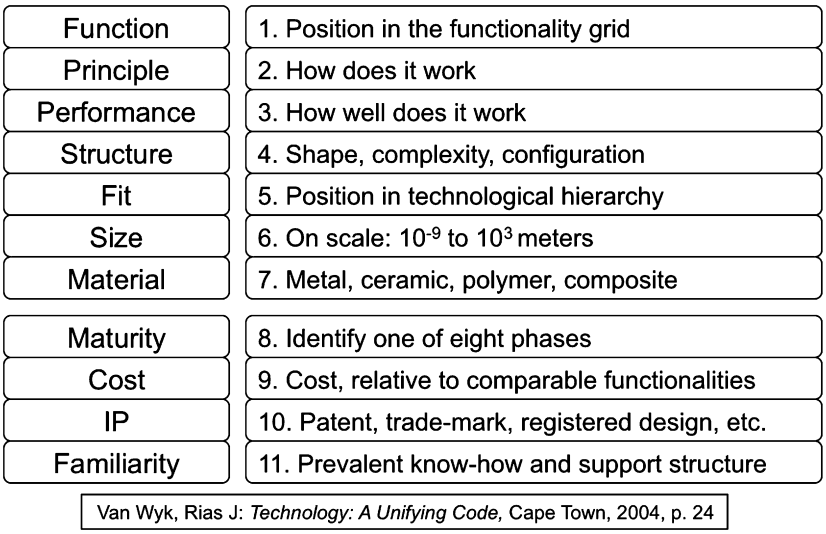

Diagram 3. Locus of technology potency.

Based on information of this kind, portfolio managers can form an impression of the relative technological potency of the company they are analyzing. They can enter an impressionistic comment in row 3 of the template.

5.4. Key technologies have a good future-fit

Future-fit exists if the key technologies are in harmony with long-term technological trends. Future-fit is poor if key technologies are threatened by long-term trends.

A feel for future-fit is obtained by comparing the key technologies with the pattern of the long-term trends that describe the emerging technological landscape. This is a challenging task.

Technology executives refer to the technology foresight studies for these long-term trends. Portfolio managers who wish to expand their knowledge into this area should use the same sources. A dedicated tool is the *Atlas of Technological Advance* that charts the evolving technological frontier. This Atlas is in an advanced prototype stage. (Van Wyk et al., 2008). Extracts from the *Atlas* are summarized in the *User's Guide* referred to in Section 4.

By comparing key technologies to anticipated long-term trends, portfolio managers should make their judgment as to the future-fit of a company's key technologies. Portfolio managers should enter a comment in row 4.

All the above indicators refer to the technological base of the company. The remaining indicators refer to organizational features.

6. Effective procedures for technological renewal

Two procedures have been identified that contribute to technological strength and potential

- exploring new technologies, and
- aligning overall strategy with technological threats and opportunities.

There are no standard practices for these procedures, and portfolio managers have to probe individual company approaches. In doing so managers may use Diagram 4 as a reference model.

6.1. Procedures exist for exploring new technologies

The following guidelines refer to items 3–5 in the above model.

Some companies are "single play" technology companies. Frequently this is the case with start-ups. Portfolio managers must ascertain to what extent a company seeks continuous involvement in technological progress, and to what extent it prefers a one-off involvement.

In the case of continuous involvement, portfolio managers have to obtain clarity on the procedures used by the company to explore and exploit technological progress. It is useful to look for four stages.

- Edify,
- explore,
- evaluate, and
- envision.

Edification is concerned with the training of technology explorers, and helping explorer's identify sources of information. *Exploration* is concerned with the actual gathering of information on technology trends, and charting the expanding technological frontier. *Evaluation* is concerned with identifying the importance of various observations and determining relevance to the company. *Envisioning* involves the selection of a profitable pathway into the future.

Portfolio managers can now form an impression on the extent to which a company uses explicit procedures to inform itself on the rate and direction of technological advance. Enter a comment in row 5.

6.2. Procedures exist for aligning strategy with technological threats and opportunities

Having probed the procedures for exploring new technologies, portfolio managers should obtain a sense of the extent to which these procedures are properly imbedded in the overall strategy process.

Distinguish between four levels of integration

- technology and strategy are *disconnected*,
- technology interests are *derived* from overall strategy,
- technology interests and overall strategy *co-determine* each other, and
- technology foresight helps *define* overall strategy.

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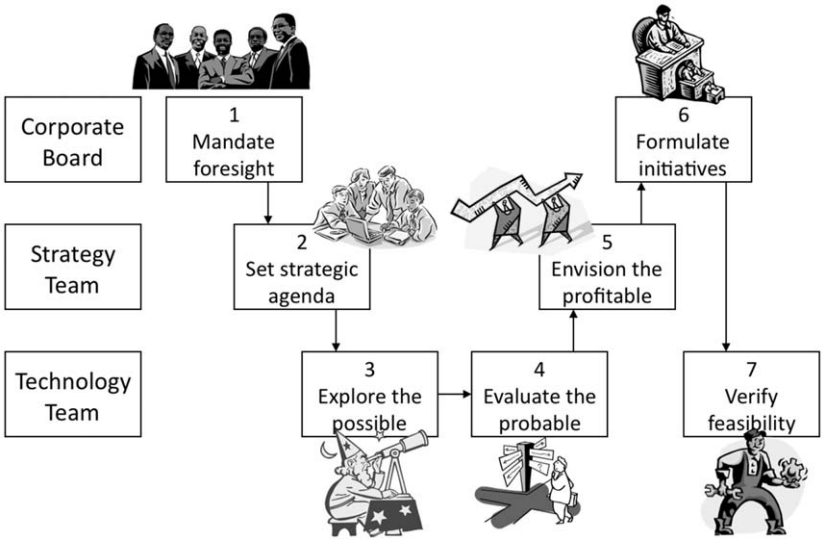

Diagram 4. Procedures for technological renewal.

There is no right level of integration. Each company follows its own approach. Bear in mind that conventional teachings on strategy do not cover the fourth level—it is not automatically present among conventionally trained corporate executives. Note the extent to which the company has grown its own expertise in this area.

Next note the existence of three actors in this framework

- Corporate Board,
- Strategy Team, and
- Technology Team.

Does each actor understand its role? Are the roles of various actors connected? Are the goals of various actors in harmony with each other? (Van Wyk and Tschirky, 2007).

This is an important perspective because practical business politics frequently cause the most improbable disconnections in the above model. Thus portfolio managers will encounter technology executives who deliberately hide their efforts in technology scanning and innovation targeting from the strategy teams and the board. In managing their innovation hotlists such executives wait until the list is finalized before introducing it into the overall strategy formation process. This kind of approach is referred to as "flying below the radar". Sometimes it works, sometimes it doesn't. The practical world is filled with diversity.

Again, there is no single, simple, process that is right. Portfolio managers have to judge the appropriateness of what they find in terms of the resilience it imparts to the company. Enter a comment in row 6 of the *Template*.

7. Technology-conversant management

The final criterion in the *Template* is technology-conversant management. What is the level of overall technological acumen among company executives?

In practice technology executives can be of different kinds. Frequently they have a specialized background in science or engineering to which they have added business experience. This may have been augmented by training in general management. Sometimes they also seek dedicated training in the management of technology (MOT).

While appropriate *specialist* skills are an inextricable part of the technology base of a company, *technology guidance* skills require an added emphasis. They require a feel for the range and reach of the technological landscape, and a sense of its evolutionary thrust.

Two managerial characteristics have been identified that contribute to this skill

- systematized technological knowledge, and
- formalized technological outlook.

7.1. Technological knowledge is systematized

The conventional business model based on the categories marketing, finance, operations, administration and human resources, was conceived in 1917. At that time technology did not have the business relevance that it has today. Technology-conversant management requires formats and skills in addition to conventional academic categories.

Portfolio mangers should ascertain what models executives use when they practice technology guidance.

Start off by clarifying what company executives mean when they use the word technology. Clarity is important because the word "technology" is applied to about seven very different and unrelated phenomena. Portfolio managers should be aware that there is no "right" use of the concept in common English. We have to accept that a wide variety of meanings have validity but it is important to judge how competently managers handle this variety and how consistent they use the term within their own company.

Next find the model, implicit or explicit, that executives use to visualize the technological totality. Be aware of four possible models

- engineering,
- thematic,
- economic, and
- functionality.

The engineering model uses categories normally associated with different engineering professional categories. These include mechanical, electrical, electronic, civil, aeronautic, and other specialties. The thematic model uses categories derived from scientific roots. These include bio-tech, nano-tech, materials technology, etc. An example would be the very popular mosaic

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of scientific fields as followed by the National Science Foundation (NSF), and the United Nations Industrial Development Organization (UNIDO). The economic model uses categories from International Standard Industrial Classification (ISIC), and the North American Industrial Classification System (NAICS). Finally, the functionality model, discussed earlier, uses the nine fundamental functionalities that underpin all industrial activity.

Based on the views expressed by company executives, portfolio managers can form an impression of whether and how executives use an explicit structure for organizing technological knowledge. Enter a comment in row 7 of the *Template*.

7.2. Technology outlook is formalized

One of the fundamental features of technology is the high rate of technological advance. Technology performance metrics (TPMs) improve at rates ranging from 5% per annum for slowly evolving technologies to 100% per annum for rapidly evolving technologies. These differential rates of change cause immense stresses and strains within the technological landscape, and call for continuous adjustments to the technology base of companies.

Technology-conversant managers have a strong sense of technology foresight. This includes an awareness of landmark technologies that will come to dominate the technological landscape in the future, and an awareness of terminal technologies, i.e., technologies that are being overtaken.

Portfolio managers should probe the mind-set of the company executives to get a feel for the degree to which executives use a structured technology outlook—as opposed to a random mosaic of opinions. A comment in row 8 completes the assessment template.

8. Using the template

The *Template* has been designed to augment present procedures followed by portfolio managers to judge the viability of investment prospects. These procedures include (i) evaluating financial information, and (ii) scrutinizing management. Judging technological strength and potential thus becomes an additional element in making the investment call.

The *Template* will help portfolio managers structure their thoughts on technology when reviewing corporate literature and conducting interviews. By using the *Template,* portfolio mangers will gain a better understanding of the technology base and its future evolution, and how the company goes about harnessing technological opportunities.

Sources of information include corporate literature and company officials. Corporate literature includes (i) the annual report, (ii) press releases, and (iii) the website. Company officials to interview include (i) The Chair of the Board Technology Committee, (ii) CEO, (iii) CTO, (iv) strategy team, (v) technology team, and (vi) investor relations professionals.

By entries in the third column of the *Template*, portfolio managers can generate a technological report card for the company. This will help them form a personal judgment of its technological strength and potential. Portfolio managers should recognize that this judgment is intuitive. The *Template* is intended as a format to support personal judgment. It has not been designed as a loose-standing checklist.

References

Bourne, Joel K., 2007. Green dreams. National Geographic 212 (4), 41–59.

CFA Institute, 2001. Candidate Book of Knowledge. CFA-CBOK^{TM}, Richmond, Virginia.

Gaynor, Gerhard (Ed.), 1998. The Handbook of Technology Management. McGraw-Hill, New York.

Clarke, D., 2004. Theory of Technology. Transaction Publishers, Edison, New Jersey, USA.

Magee, C.L., De Weck, O.L., 2004, Complex system classification. Fourteenth Annual International Symposium of the International Council on Systems Engineering (INCOSE), 20–24 June.

Perez, C., 2002. Technological Revolutions and Financial Capital. Edward Elgar, Cheltenham, UK and Northampton, Massachusetts, USA.

Ropohl, G., 1979. Eine Systemtheorie der Technik. Carl Hanser Verlag, München.

Van Wyk, Rias J., 2004. Technology: A Unifying Code. Stage Media Group, Cape Town.

Van Wyk, Rias J., 2008. Technology Assessment Template: A Users Guide. Technoscan Centre, Edina, Minnesota, USA.

Van Wyk, Rias J., Karschnia, Bob, Olson, Wayne, 2008. Atlas of technological advance. Research Technology Management 51 (5), 61–66.

Van Wyk, R.J., Tschirky, Hugo P., 2007. A board charter for technology. Director's Monthly 31 (7), 15–18.

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