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Transforming R&D Expenditures into Innovation: Identifying and Evaluating Effective Metrics to Track the Effectiveness of R&D in Software Innovation

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TRANSFORMING R&D EXPENDITURES INTO INNOVATION: IDENTIFYING AND EVALUATING EFFECTIVE METRICS AND METHODS TO TRACK THE EFFECTIVENESS OF R&D IN SOFTWARE INNOVATION

by

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ABSTRACT

Transforming R&D expenditures into Innovation:
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by **Mathias Nöbauer MSc**

Chairperson of the Supervisory Committee: ______________________
WU Wien

"How much of HP's R&D-spend delivers innovation?" Russ Daniels, HP's CTO for Software pointed out to me that this is a central question for HP and that the measurement of the transformation of R&D efforts into software innovation would be a topic worthwhile to investigate. The approaches which are currently applied within HP to measure the 'innovativeness' of software R&D are not sufficient. An exploration is needed to identify more sophisticated metrics or methods to measure the use of R&D in software innovation. This is the key goal of this thesis. An answer to this important question is of direct relevance and interest for the CEO of HP.

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GLOSSARY

Development. Use of scientific or technical knowledge in order to produce new or substantially improved materials, devices, products or services, to install new processes or systems prior to the commencement of commercial production or commercial applications, or to improving substantially those already produced or installed (US-Government, 1988).

Effectiveness. Producing a decided, decisive, or desired effect (Merriam-Webster, Effectiveness)

Efficiency (economics). A general term, to capture the amount of waste or other undesirable features (Wikipedia, Efficiency)

Innovation. Commercialization of an invention (see also *Chapter 1 – "the definition of innovation"*).

Invention. New concepts or products that derive from individual's ideas or from scientific research.

Open Innovation. The use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology. (Chesbrough, et al., 2006)

Open Source. Open source is a development methodology, which offers practical accessibility to a product's source (goods and knowledge). The principles and practices [*of the open source model of operation and decision making*] are commonly applied to the development of source code for software that is made available for public collaboration, and it is usually released as open-source software. (Wikipedia, Open source)

R&D. Research & Development.

pure (or basic) **Research**. Experimental or theoretical work undertaken primarily to acquire new scientific or technical knowledge for its own sake rather than directed towards any specific aim or application. (US-Government, 1988)

Chapter I: Introduction

1. PROBLEM STATEMENT

According to Peter Drucker, "Innovation is the effort to create purposeful focused change in an enterprise's economic or social potential." (Drucker, 1998)

This perspective outlines that innovation is an essential focus area for today's business leaders. Especially since "innovation is the key element in providing aggressive top-line growth, and for increasing bottom-line results. Companies cannot grow through cost reduction and reengineering alone." (Davila, et al., 2006)

Although companies can grow through other means, they might probably not be fast enough – if you consider expected growth rates on capital markets.

This is in line with IDC's 2007 survey of CEO business priorities (fgens, 2007), which shows that executives want to break out of the commodity trap: 'Improving product and service innovation' moved from #4 (2005) to #2 (2006) – staying at #2 in the year 2007.

The growing focus on greater (and faster) innovation in product and service offerings seems to be directly tied to growing competitive pressures of globalization. IDC predicts that 'Innovation' would remain in the #1 or #2 spot as long as globalization pressures are escalating.

The survey also shows that better 'Business performance monitoring' (#5) and 'IT responsiveness & efficiency' (#6) are ranked very high on the agenda.

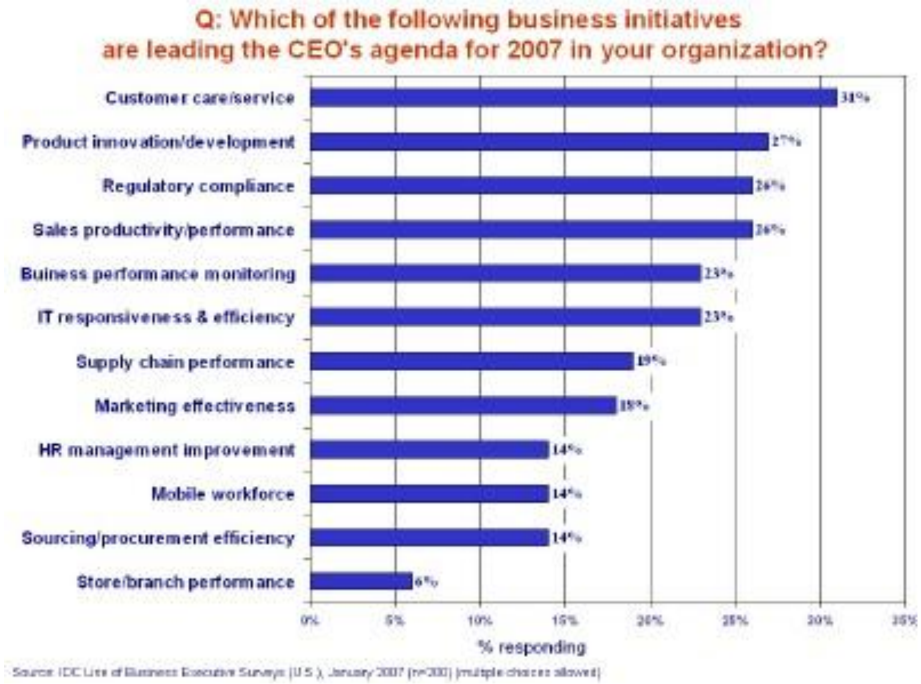

Figure 1. IDC: CEO Agenda for 2007: Customer Care and Innovation On Top Again (fgens, 2007)

So, measuring innovation seems to be important from the perspective of two very important initiatives ('Product innovation/development'; 'Business performance monitoring'). In general executives seem to be very keen on getting numbers that give a good indication about the 'innovativeness' of their organization. Ideally they would also like to get the opportunity to use benchmarks which they can compare against others – preferably those of competitors:

"The only way to know whether the company is efficient is by benchmarking its performance." (Nayak, 1992).

Some researchers say that innovation performance is hard to control or not controllable at all: "Researchers do not necessarily exhibit more innovative behavior when they perceive relatively loose administrative control than when they perceive tight control" (Kamm, 1980).

However many others (Davila, Epstein and Shelton) convincingly argue that innovation performance is indeed controllable and improvable. Clear goals and measurements are necessary to make sure that the organization is heading towards the right direction. Or to use Peter Drucker's words once again: "If you can't measure it, you can't manage it."

But the issue itself is not a new one. In a Harvard Business Review article from the year 1957 Charles Orth describes an approach how to measure performance of engineers in the chemical and electrical industry using simple methods (Orth, 1957).

Although there have been some approaches published in the meantime that describe methods and metrics to evaluate the 'innovativeness' of organizations or products, none of those seem to be well established in practice yet. Some of them are hardly applicable for Software R&D. And I did not discover any well established approach that is specific to Software R&D.

However, many organizations seem to put more focus on innovation and seem to aim for better metrics and methods of measurements in that area – particularly in the software industry.

The goal of this paper is to identify more sophisticated metrics or methods to measure the use of R&D in software innovation.

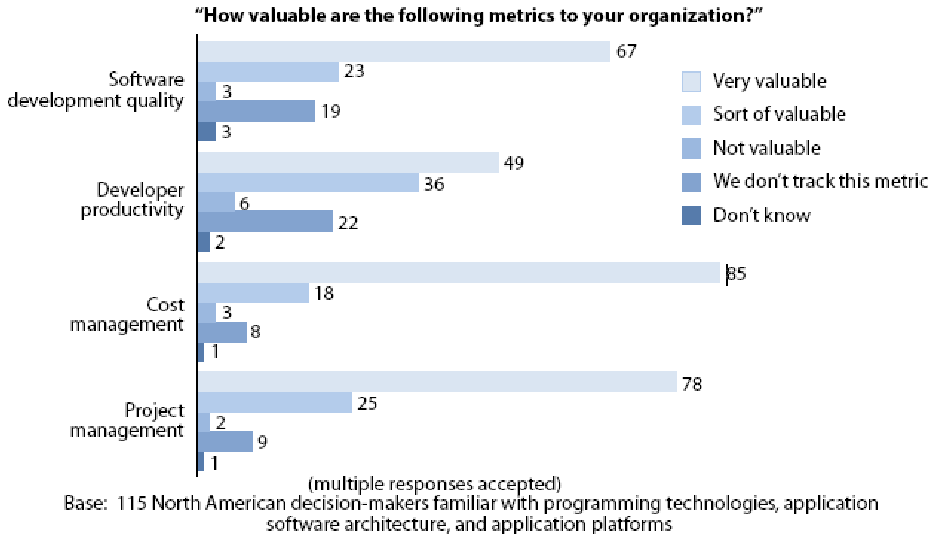

Figure 2. Forrester Research: Tracking And Valuing Application Development Metrics (Barnett, 2005)

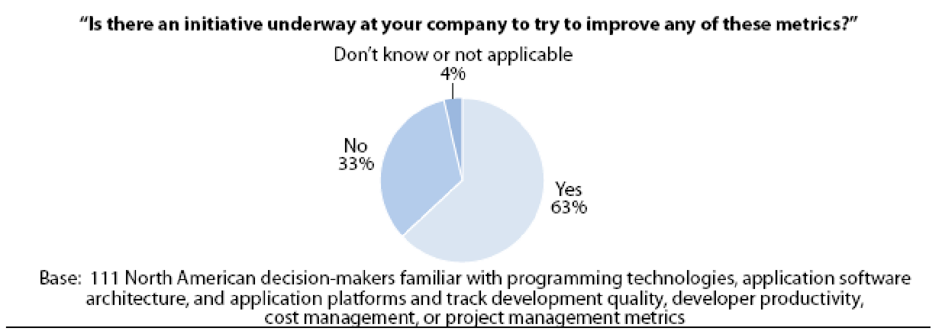

Figure 3. Forrester Research: Initiatives Underway To Improve Metrics (Barnett, 2005)

2. THE DEFINITION OF INNOVATION

The word 'innovation' is nowadays used very frequently across various domains, but only a few people have a clear understanding of its meaning.

Unfortunately there is no common definition of the word 'innovation' in literature. Sometimes authors tend to bend the meaning of 'innovation' to fit their specific interest or goal.

Besides some widely spread definitions of 'innovation', like the one of Schumpeter in the 1930s, the following one is particularly clipped and precise:

"[A]n innovation […] is any new or substantially improved good or service which has been commercialized, or any new or substantially improved process used for the commercial production of goods and services. 'New' means new to your business." This definition is taken from the 'ABS' questionnaire, which is Australia's most comprehensive innovation survey.

As commercialization is a key aspect behind the term 'innovation' it has to be clearly distinguished from the term 'invention':

"The first confusion to dismiss is the difference between invention and innovation. The former refers to new concepts or products that derive from individual's ideas or from scientific research. The latter, on the other hand, represents the commercialization of the invention itself. […] Dr. Crawford put it this way: Innovation happens when you figure out how to make money from an invention." (Boothby, 2006)

This is an important distinction that should be made when discussing how to measure the use of R&D in (software) innovation. To restate this from a different perspective:

„In general, innovation is only regarded to have occurred if it has been implemented or commercialized in some way. The creation of abstract knowledge, or the invention of new products or processes, is not normally considered innovation until it has been productively incorporated into the enterprise's activities. This means that innovative activity is not something that can occur separate from the firm's core activities, rather it must involve the coordination of various inventive, learning and implementation skills." (Rogers, 1998)

This suggests that R&D plays a major role in innovation processes – although it <u>alone</u> cannot be held responsible for innovation. Various other organizational functions have to be involved, e.g. specifically for the commercialization aspect (e.g. Marketing and Sales).

3. SOFTWARE R&D

"Science is the systematic study of the nature and behavior of the material and physical universe, and technology is practical application of science, especially in industry and commerce. The process by which the new scientific and technological information is discovered, gathered and used involving theoretical conjecture, observation, experiment, measurement and deduction, is referred to as 'research and development' (R&D)." (US-Government, 1988)

The nature of R&D organizations in the software industry differs from R&D organizations in other industries. The difference appears mainly because in the software industry there is mostly no explicit distinction between production activities and the activities which are being referred to as R&D activities in other industries. The output of R&D organizations in the software industry is typically a ready-for-market product, whereas in typical R&D organizations the expected output is primarily new knowledge.

This difference is also recognized by Government organizations, which in practice have to "distinguish between genuine innovative work of the sort they want to incentivise and work which is the routine adaption of existing materials, products, processes recognized or services" (UK-Government, 2003) for tax purposes.

Existing guidelines, like the one of the US government discuss software specifically in a number of paragraphs:

"Software R&D might include investigations in such areas as theoretical computer science, new operating systems, new programming languages, significant technical advances in algorithms, new or enhanced query languages, or object representations, software engineering methodologies for improved computer programs and artificial intelligence. […] The development of, say, a new natural language interface for a computer game could qualify as R&D, although the game may be a mature product and represent non-R&D activity in most other respects." (US-Government, 1988)

The last statement makes it clear what this means in practice for many leading software firms. In the case of Hewlett-Packard Corporation (HP) some of the work which is done in the 'Software R&D' organization could qualify as R&D (e.g. the development of the Topology Query Language: TQL [developed by Mercury Corporation before its acquisition by HP]), whereas most of the work is probably not considered to be R&D:

"Software-related activities of a routine nature are not considered to be R&D. Such activities include work on system-specific or program-specific advancements which were publicly available prior to the commencement of the work. Technical problems which have been overcome in previous projects on the same operating systems and computer architecture are excluded as are activities such as:

- supporting existing systems;
- converting/and or translating computer languages;
- adding user functionality to application programs;
- de-bugging of systems;
- adaption of existing software;
- preparation of user documentation;

[…] These do not involve scientific and/or technological advances, and are not classified as R&D." (US-Government, 1988)

From a taxation perspective this differentiation is more difficult than it seems and meanwhile government organizations are asking themselves if it really makes sense to distinguish:

"Perhaps it would actually have been clearer not to address software specifically, beyond noting that it is to be treated on par with other areas of R&D." (UK-Government, 2003)

Besides their 'Software R&D' department some big software vendors decided to run dedicated R&D organizations (like 'HP Labs' at Hewlett-Packard Corporation). Those are focused on pure R&D activities – like the discovery of new scientific and technological information –, whereas HP Product Divisions (like HP Software) are mainly working on productizing innovations.

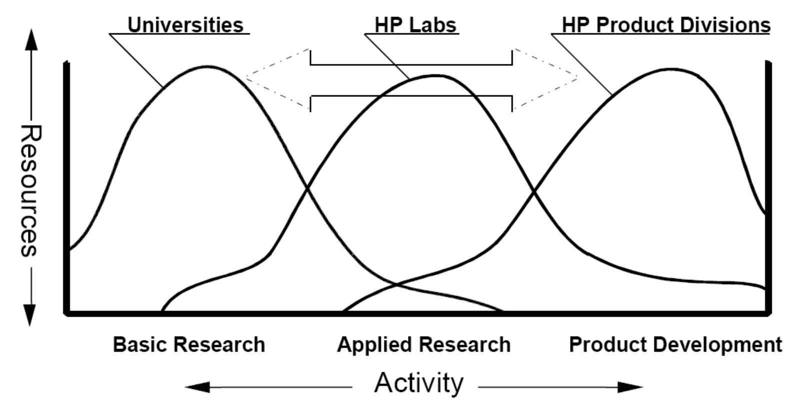

Figure 4. Focus of R&D Activities at HP (Wyleczuk, 1998)

Having made this distinction, it should be mentioned that the focus of this thesis is on 'Software R&D'.

And it should be emphasized again that it is not the sole responsibility of R&D to create innovations:

"… the definition of R&D is unlikely to match exactly with innovation. That said, its wide availability and the expected high correlation between R&D and innovation effort make it a valuable proxy for innovation activity." (Rogers, 1998)

For typical R&D organizations this correlation is questioned by a number of researchers, especially since the advent of 'Open Innovation'[1]. However, the statement is (even) more adequate for 'Software R&D', as this type of organization produces the products and features that are (partly) commercialized as innovations. Furthermore a close integration of customers in the new product development process is already (relatively) common in the software industry. Which is important, since customer involvement in the new product development process is considered to be critical across industries today (Haven, 2007).

[1] (von Hippel, 2005), (Wecht, 2005)

4. DIFFERENT PERSPECTIVES

Literature describes a number of different roles in Innovation Management – with their distinct perspectives. When defining metrics or methods for measurement, one should make sure that the specific demand of the target group is met.

This document focuses primarily on the metrics and methods that are potentially relevant for managers in today's organizations in practice – across various levels of hierarchy.

Being aware that there are various roles with different areas of focus should help to classify thoughts in this domain. The following five varieties are sometimes being referenced in literature.

"Gopalakrishnan and Damanpour provide a large bibliography, giving examples of all five varieties. According to Gopalakrishnan and Damanpour the problems that companies have in finding multiple-skill personnel are duplicated in the academic world. Each of these five domains can present a valid view of an innovative practice. It is very rare that one of them has been able to deal with the problem in all its diversity." (McCosh, et al., 1998)

TARGET GROUP	FOCUS
Economists	… do not really regard innovation as a managerial process, merely as a surrogate for spending on R&D or as a measure of new products generated. Innovation, for them, is a very gross and aggregated measure, and they do not really study it as itself.
Contextual technology researchers	… study innovation in much closer detail, but still at the level of industry context. Their goal is to help firms manage technological transitions.
Organisational technologists	… consider the same problems, but from the inside of a single firm.
Variance sociologists	… study why innovations are adopted quickly or slowly in a firm, and also explore whether a company has features which make acceptance easier or harder.
Process sociologists	… regard innovation as a continuous process and study it as such.

Table 1. Perspectives on Innovation Management
(McCosh, et al., 1998)

5. OVERALL GOAL

Due to growing market power of customers, companies are facing shorter product lifecycles and lower market prices. Therefore yields for products that are already on the market are typically decreasing. If companies are not able to compensate this effect with higher sales, it means there is less capital available that can be invested to expand the business – which also means fewer resources for the innovation process.

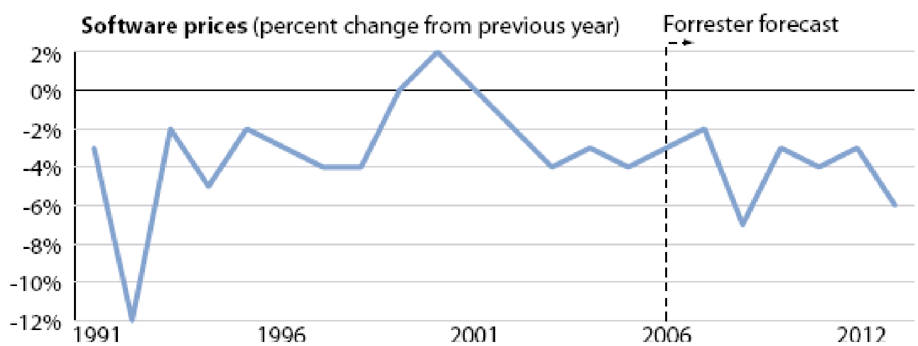

Figure 5. Forrester Research: Software Prices Will Fall More Rapidly from 2006 To 2012 (Bartels, et al., 2006)

Some companies are (already) heavily depending on external sources to obtain financial resources, which results in heavy competition for capital on capital markets.

Therefore the shareholder value has put itself into the center of examination in business. Maximizing the shareholder value is typically the overall goal - as demanded by providers of capital. Furthermore lenders of capital expect significant improvements in productivity and transparency of profit margin and return of investment.

Empirical studies show that companies which are investing in new products (and therefore R&D) and new markets are increasing their company value. (Werner, 2001)

But this statement has to be treated with care, since various studies come up with different conclusions:

"Research and Development can also be seen as a proxy for innovation, provided that the money is used (invested) wisely.

Chan et al. (2001) find no reliable evidence that support a direct link between R&D spending and stock returns. However, Johnson and Soenen (2003) find in their study that there exists at least a weak link to company performance (measured by EVA) but this effect is a negative one. Damanpour and Evan (1984) report a positive relationship between innovation and performance. Similarly, Subramanian and Nilakanta (1996) also find that innovativeness has a positive effect on performance when measured by return on assets. Aboody and Lev (2000) find that performance (measured by insider gains) is higher in companies with a relatively high R&D intensity. Based on the convincing results of most previous studies it is assumed that Research and Development expenditure relative to sales has a positive effect on all three performance measures. When a company is able to be innovative trough Research and Development the profitability as well as the cash flow will rise. Investors are also expected to invest in attractive and innovative companies, which have a positive future perspective. Additionally, a time lag of two years is introduced to account for the gap between the date when the money is invested and the date when the results can be seen on the balance sheet, and on the stock price respectively." (Hörbarth, 2006)

Vice versa it can be stated that the shareholder value mindset has got a major impact on investments into the future – and therefore on R&D. Potential reactions of companies are:

- reduce cost for R&D
  (in the software industry this could be achieved through: platform strategy, reuse of software components, reuse of knowledge)

- reduce the duration of the R&D process
  (to achieve: shorter product lifecycles, quicker time to market, optimize point in time for market entry)

- expand the product lifecycle
  (car manufacturers could significantly expand the product lifecycle by applying 'facelifts'; in the software industry this could be achieved through reuse of software components across various products or by positioning products in other markets [e.g. adapt 'HP Project- and Portfolio Management'-software and position it outside IT departments {EPMO, Stage-Gate Process for Innovation Management}])

- follow new approaches, like 'Open Innovation'
  (there are various options in the software industry to leverage external resources, e.g. participate in open innovation networks [use the Eclipse client for 'HP Service Manager'-software])

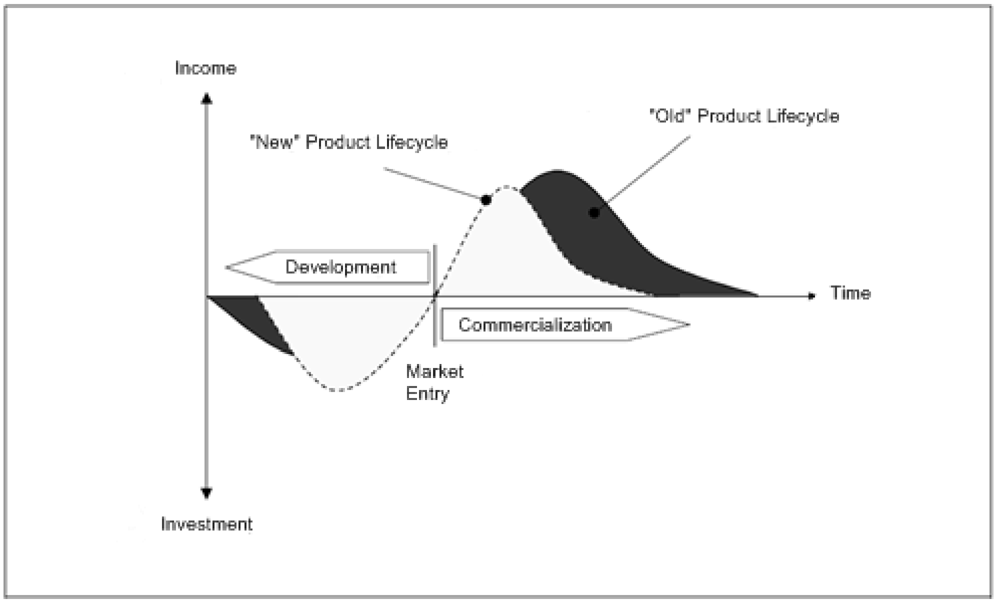

Figure 6. The Evolution of the Product Lifecycle (Werner, 2001)

6. OPEN INNOVATION NETWORKS IN THE SOFTWARE INDUSTRY

"The central idea behind open innovation is that in a world of widely distributed knowledge, companies cannot afford to rely entirely on their own research, but should instead buy or license processes or inventions (i.e. patents) from other companies. In addition, internal inventions not being used in a firm's business should be taken outside the company (e.g. through licensing, joint ventures, spin-offs). In contrast, closed innovation refers to processes that limit the use of internal knowledge within a company and make little or no use of external knowledge. Some companies promoting open innovation include Procter & Gamble, Innovation Exchange, NineSigma, InnoCentive, and IBM." (Wikipedia, Open Innovation)

Open Innovation provides (radical) opportunities for the software industry. Software development cost structures today have limited correlation to creating value for customers. Many software companies are putting a good portion (~80%) of their investment into 'build and support infrastructure' for which companies derive zero differentiating product value[2].

Shared implementation of infrastructure allows to

- save time to market
- increase rate of standards adoption
- reduce risk
- provide thought leadership and first mover advantage

[2] (Eclipse, 2007)

However, this does not mean that software vendors cannot compete anymore. They will continue to compete on product differentiating features (e.g. HP discovery technologies or HP Topology Query Language), service, support, branding and channels.

Therefore using open source software can be considered as a way to increase shareholder value. One company which has proven to make use of Open Source software to improve bottom line results is Apple:

"This is another example of how Wall Street is hopelessly amiss in the knowledge economy. […] Measuring success in innovation by looking at the size of the R&D budget is like figuring out how successful a song (or a film or a book) will be by measuring how long the creator took to write it. […] The development of OS X proceeds steadily with no missed deadlines and with a consistently improving feature set and significant resulting user experience improvements. To achieve this, OS X leverages significant amounts of open source technology for both reasons of standards as well as development effectiveness. From an R&D perspective the development costs of OS X are tiny compared to Vista, some have estimated Microsoft QA team is larger than the entire OS X development team. […] Clearly, judging R&D spending by metrics derived by both revenue methods or relative product development models is foolhardy and grossly primitive. […] Apple has succeeded because they start with user experience and then determine the most effective means to execute the technology (i.e. the underlying use of open source technology such BSD unix, open GL, apache, php, mysql, ajax, browser engine and printing technology, etc.). The user experience extends to packaging, software installation, product design, integrated applications, interface design etc. even to include clever product naming. Clearly, it is not the amount Apple spends that is important but the much more complex

and interesting way Apple is strategic about allocating its resources.”
(BusinessWeek, 2006)

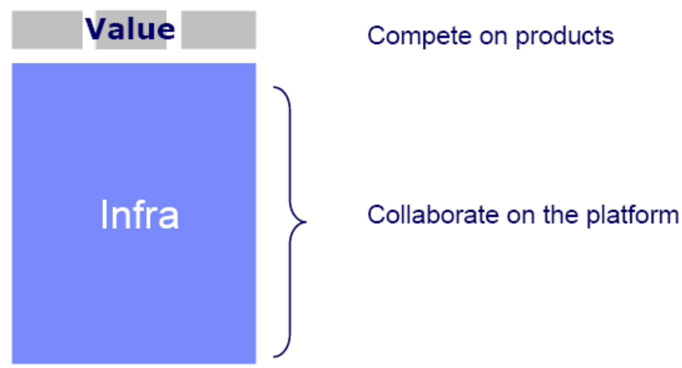

Figure 7. Build Infrastructure in and with Open Source, even if that means working with your Direct Competitors. (Eclipse, 2007)

When leveraging open source vendors should:

- define <u>very</u> precisely what their competitive differentiators for their customers are

- focus all possible energies there, and acquire everything else from open source software, or help build it in open source software

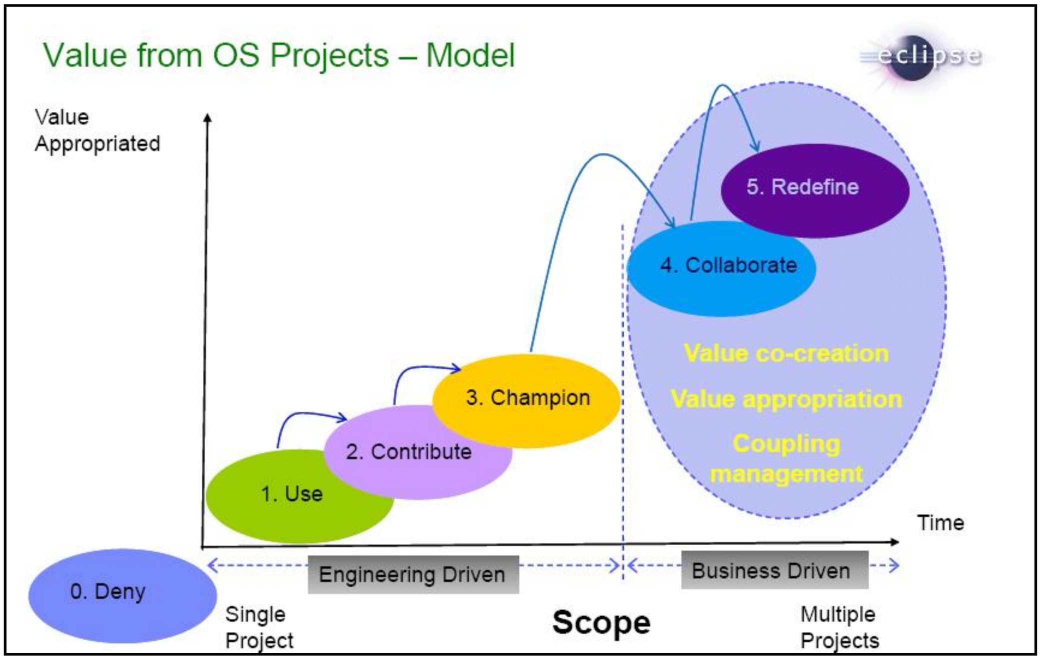

Figure 8. Value from Open Source Software projects. (Eclipse, 2007)

Apart from actively participating in external networks of software communities, some large corporations, like HP (Melian, et al., 2002), use similar principles to build networks inside their organization.

7. ROLE OF SENIOR MANAGEMENT IN THE NEW (SOFTWARE/) PRODUCT DEVELOPMENT PROCESS

As outlined in the previous paragraphs, innovation management has got a significant impact on bottom-line business results. Furthermore innovation management cannot be restricted to R&D alone. Therefore senior management attention and involvement in the area of innovation management is critical, especially since some decisions that are often made within R&D influence the corporate strategy (e.g. the use of open innovation).

"The majority […] assume a positive impact of senior management support to new product development activities on performance. However, there is neither strong empirical evidence for this relationship nor does the existing literature specify how senior manager, which are committed to innovation affect different performance measures." (Gomes, et al., 2001)

Deriving the mission and goals (for the new product development [NPD] process) from the company strategy and communicating those accordingly, is important to steer towards the right direction.

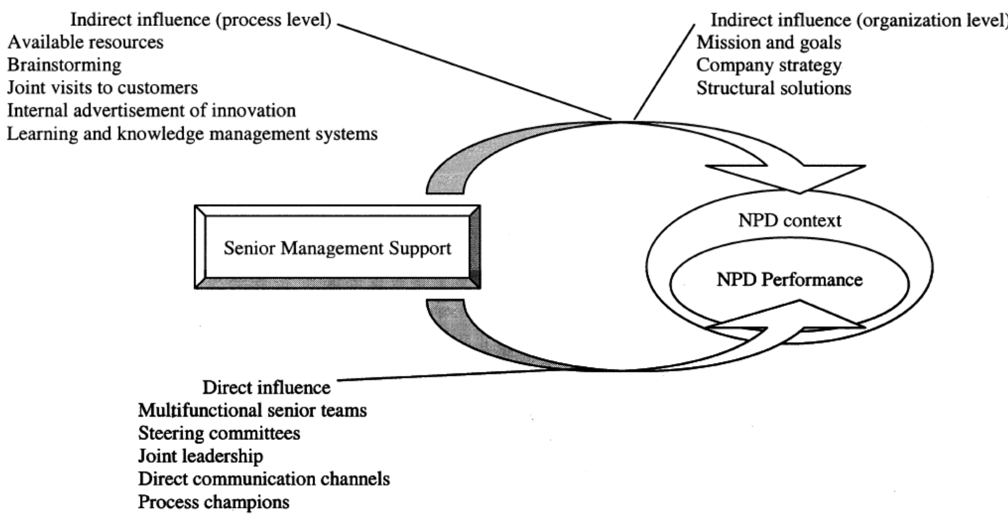

Figure 9. Senior Management Support to New Product Development: Perceived Practices (Gomes, et al., 2001)

I identified a number of persons in leading software companies, who were willing to share their experience in that field with me. Interestingly the measurement of effectiveness and efficiency (with regard to innovation) are not well established in practice yet.

And although senior management is interested in those figures, innovation metrics are not yet part of performance management frameworks (see example below).

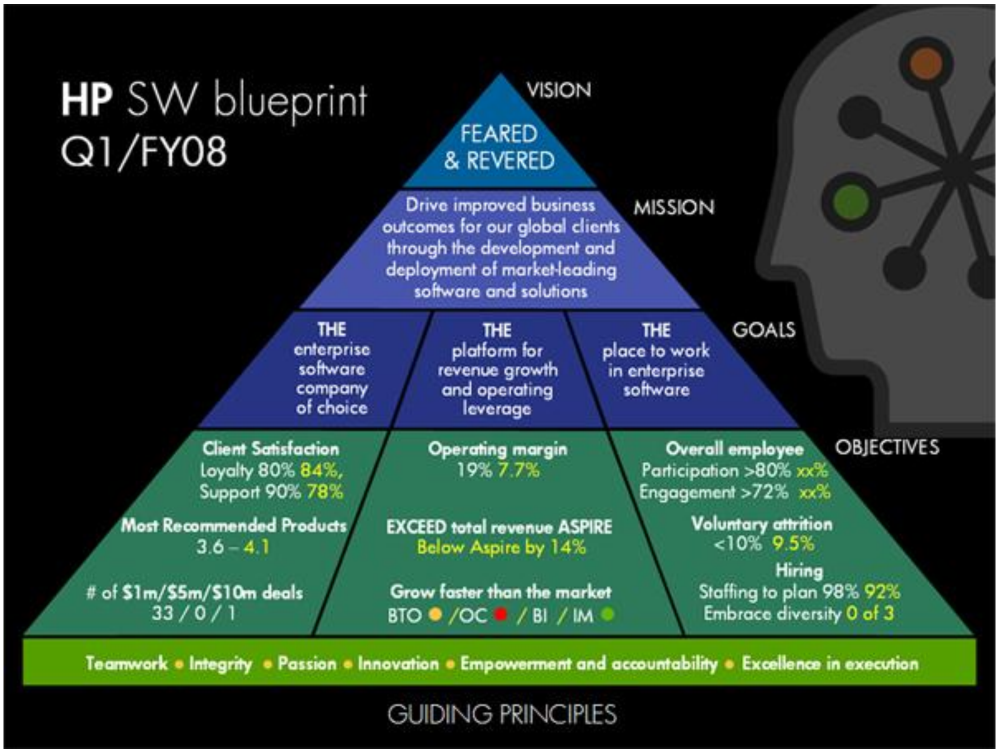

Figure 10. HP Software Blueprint including Established Measures.

"Few companies measure their innovation efforts as carefully as they measure other aspects of their business; some companies barely attempt to measure innovation at all. [...] Most companies recognize the importance of measurement, but few believe they are doing it as well as they should. Only 37 percent of survey respondents said they were satisfied with their company's measurement practices." (Andrew, et al., 2007)

As a consequence it can be expected that Senior Management of leading software companies will put more emphasize on the measurement of innovation in the upcoming months and years.

8. SOFTWARE DEVELOPMENT PROCESSES

There always was – and still is – a lot of discussion going on about how much R&D organizations should be governed. The following excerpt comes from a speech given at the Yale School by Lew Platt.

„Bill Hewlett tells an interesting story about the dynamic tension between the creativity that leads to innovation and the hard-headed practicality required to bring a product to market and earn the profit that makes possible the next round of creativity. In a 1986 speech on creativity, Bill recalled the time he quoted Thomas Edison to an HP engineering manager. You've probably heard Edison's famous quip, 'There ain't no rules around here. We're trying to accomplish something.'. When Bill said that, the HP manager replied, 'Don't say that. Creativity is what screws up my engineering schedule.' Bill then recognized that 'these two comments say a great deal about the creative process. It works well when it is not too structured. But, in the end, it must be tamed, harnessed, and hitched to the wagon of mankind's needs."' (Wyleczuk, 1998)

Software development methods and tools do change rapidly, but software development processes are still often immature and poorly organized – one of the fundamental reasons why so many applications perform poorly, are unstable, insecure or provide a bad user experience.

Standardized, consolidated and mature processes are a requirement to make use of more sophisticated measurements in software development organizations.

But even then, there is limited support for data collection and analysis, as there are no standards for metrics. And there is a reluctance to introduce measurement because the benefits are unclear – especially for lower level management and individual contributors.

Many companies realize the need for more governance and effective use of processes in software R&D. Pressure for more Business-IT alignment seems to increase the traction of agile development methods, like SCRUM, again. With the advent of those methods, a number of new metrics are being discussed by analysts and effectively used by at least some organizations. Figure 16 shows some of those metrics for Agile projects.

Type of metric	Example	Comment
Project/cost management	Broad estimation (days, dollars); actual versus estimates	Need to speak in language that business management expects
	Functionality used versus built	Don't build (and therefore pay for) what you won't use
Productivity	Velocity = number of units completed in an iteration Average productivity = velocity/ number of team members	No standard size for an Agile "feature" or unit of work, so managers cannot compare across projects or companies
	Number of features delivered versus planned Percentage of features delivered versus planned	There is no percentage complete on an individual item — it is either done or not done
	Number of tests/test points completed	The number of acceptance tests for a feature is usually proportional to the feature's size and complexity
Quality	Number of defects found in production (by priority, severity, source)	Real cost of fixing a bug is directly tied to when it is found
	Rate of discovery Rate of discovery versus rate of resolution	Trends in defects over time

Figure 11. Forrester Research: Operational Excellence Metrics for Agile Projects.

I assume the advent of a dominant (agile) software development methodology will increase the maturity level of the actual software development processes used in practice. And with that increased level of maturity continuous improvement will appear as a focus-topic for many organizations. This will drive the importance of metrics and methods.

9. INNOVATION PERFORMANCE = EFFECTIVENESS + EFFICIENCY

"“In the software world, productivity tells me nothing about the value of the software produced. I think that most companies would be much better off if they focused on the effectiveness of their software development instead of the efficiency of it. I'd be willing to take a productivity hit if it meant that I could be more effective with my development and generate more value.” Lead architect, software and services company" (Barnett, 2005)

Effectiveness and Efficiency are dependent on each other. This is particularly true with regard to Innovation Performance.

Being efficient (striving towards the goal with relatively little effort) is meaningless if the outcome is not what it should be like (meeting the goal effectively).

As well it is not sufficient to focus on effectiveness if the goals are being reached by inefficient means (e.g. with disproportional with effort).

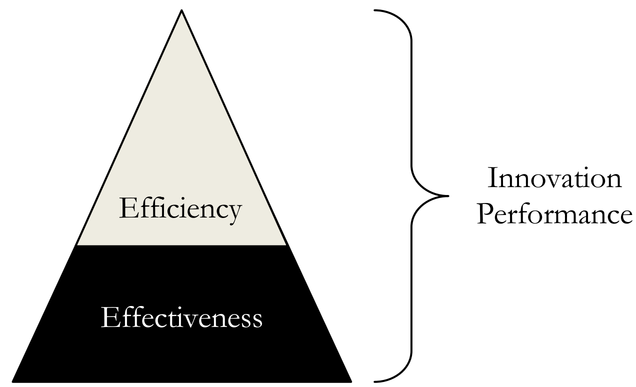

Figure 12. Relationship of Effectiveness and Efficiency (Werner, 2001)

“Efficient processes are not outright effective, but effectiveness is a necessary requirement – and therefore the basis – for efficiency and therefore for the overall performance” (Werner, 2001)

10. INPUT-PROCESS-OUTPUT MODEL

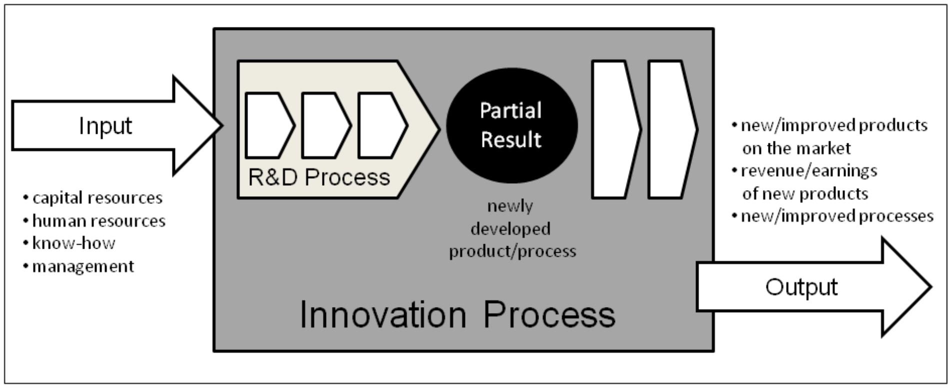

Figure 13. Input-Process-Output Model of the R&D and Innovation Process (Werner, 2001)

The Input-Process-Output Model of the R&D and Innovation Process outlines an abstract structure which represents the Innovation-/R&D-process. This simple model is often used in literature to describe the scope of measurement. It is generic enough to be applicable for different industries and sizes of organizations. And it allows for a combined view of Efficiency and Effectiveness.

Apart from that it clearly outlines that R&D is only a part of the overall Innovation Process, and other processes (e.g. Marketing and Sales) have to take care that the newly developed products/services make it to the market/customers (Output).

Efficiency in this model is the ratio between Output-streams and Input-streams. Optimum efficiency is being reached when a maximum Output-combination is achieved with a minimum Input-combination.

A maximum Output-combination is sometimes wrongly referred to being the measure for Effectiveness. But Effectiveness is about "doing the right things" – which means the result (Output-combination) has to reflect and support the strategic goals of the organization.

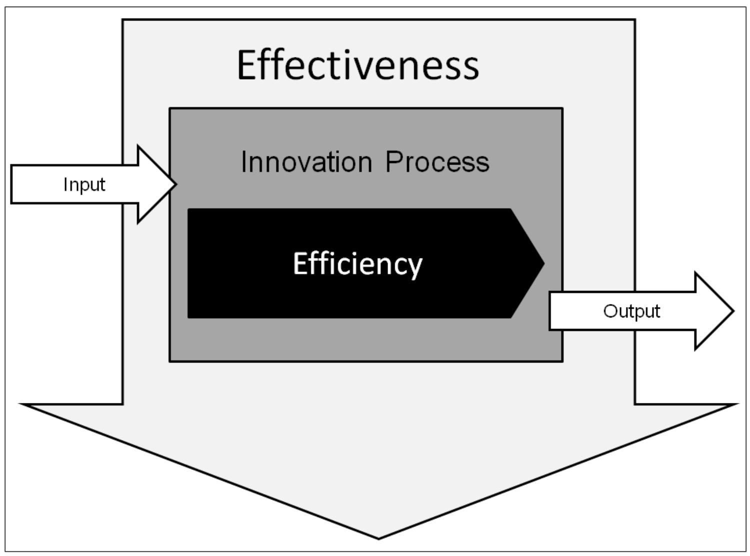

Figure 14. Effectiveness in the Input-Process-Output Model (Werner, 2001)

11. MEASUREMENT METHODS

In the area of Innovation Management three essential methods for measurement are potentially applicable (Werner, 2001):

1. Quantitative methods
2. Qualitative methods
3. Combined, integrative methods

ad 1) Quantitative methods rely on figures and algorithms. Unfortunately many of the aspects of innovation management are difficult to quantify. And – so far – relatively little data is being collected in practice that can be effectively used for our purpose. However, when using the Input-Process-Output Model you can think of a number of feasible variables that could potentially be measured. And based on those variables ratios can be calculated, which should provide some good indication about the innovation performance.

ad 2) Qualitative Methods rely on intuitive judgment of respondents. The quality of their response is highly dependent on how well structured and defined the innovation process is. Self-assessments, peer reviews and assessment centers are some common practices when using qualitative methods.

ad 3) Many analysts and researchers recommend to combine quantitative and qualitative methods.

12. COLLECTION OF METRICS

The appendix contains a table of about 250 metrics that are potentially applicable to measure innovation performance in Software R&D.

Those metrics are coming from various sources and cover different aspects. The sources sometimes contain much more metrics, but if they are not included in this table they are unlikely to be applicable to measure innovation performance in Software R&D. E.g. as the following table shows, certain metrics from typical R&D environments are also of interest in Software R&D – but some are not.

	Mean	Variance
1. Quality of output or performance	5.752	1.371
2. Unit's degree of goal attainment	5.715	1.009
3. Amount of work done on time	5.073	1.511
4. Unit's level of efficiency	4.561	2.257
5. Percentage of project completions	4.504	2.652
6. Percentage of results adopted by company	4.347	2.562
7. Frequency of cost overruns	3.746	3.166
8. Number of patents or copyrights	3.699	3.032
9. Percentage of project approvals	3.380	3.504
10. Number of technical reports produced	3.325	2.729
11. Unit profitability	3.083	4.094
12. Number of papers presented at professional meetings	3.057	2.808
13. Number of professional rewards or honors	2.992	2.587

Figure 15. Average Frequency of use (1=never, 7=always) of Metrics to Measure R&D Performance (Werner, 2001)

I also included metrics that are potentially outside Software R&D, but give a good indication about the overall innovation performance, like some of the metrics quoted by BCG in their "Measuring Innovation 2007" report:

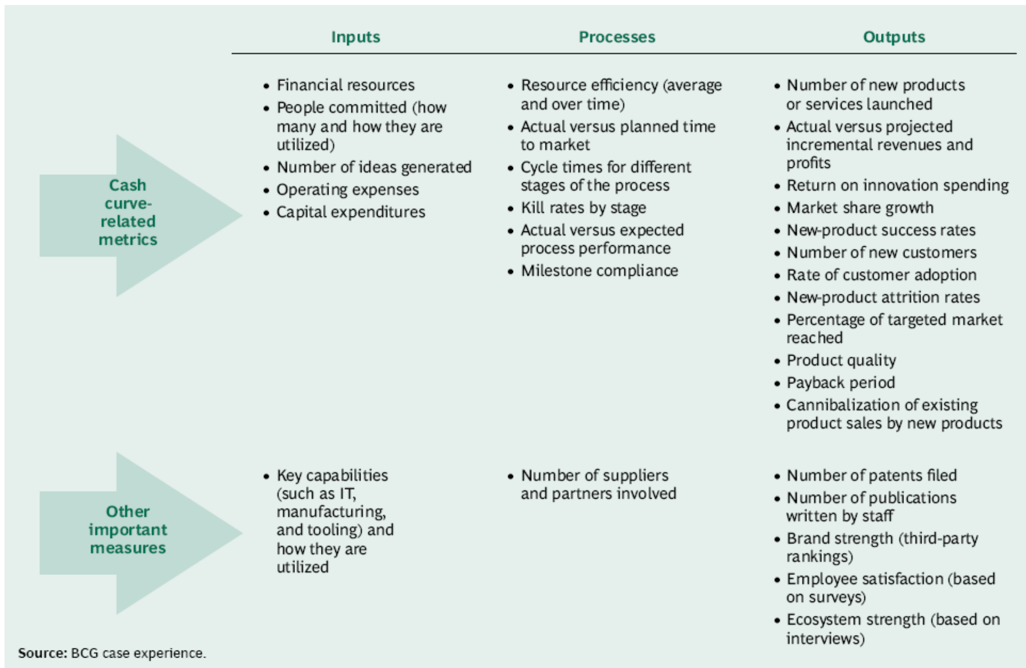

Figure 16. BCG: A Carefully Chosen Suite of Metrics Will Cover All the Key Aspects of Innovation (Andrew, et al., 2007)

The following paragraphs discuss a number of metrics that can be potentially used to effectively measure certain aspects of innovation performance of Software R&D. Table 2 contains a list of those metrics, including ratings for the "Suitability of [the] Metric" and the "Effort/Requirements to implement" the metric. These ratings are generic and have to be adapted to reflect the actual situation of any organization (e.g. available processes and systems (e.g. effort tracking), software development methodologies (e.g. agile or non-agile), strategy (e.g. use of open source software)…).

Metric	Suitability of Metric[3]	Effort/Requirements to implement Metric[4]
Input Metrics		
Ideas	★★★★☆	$
Learning Behavior	★★★★☆	$$
Process Metrics		
Maintenance vs. New Functionality	★★★★★	$
Focus Factor	★★★★☆	$
Velocity	★☆☆☆☆	$
Actual vs. Estimate	★★★☆☆	$
Time to Market	★★★★☆	$$
Value Derived from Reuse	★★★★☆	$$
Value Derived from Open Source Software	★★★★☆	$
Product Platform Effectiveness	★★★★☆	$
Prototypes	★★☆☆☆	$
Output Metrics		
Unique Selling Points (USPs)	★★★★★	$
Measuring Development in Business Terms(/Value)	★★★☆☆	$$
SCRaP	★★★★★	$$
Patents	★★☆☆☆	$

Table 2. Collection of Metrics

[3] The rating for "Effort/Requirements to implement Metric" specifies if the implementation of this metric **typically** involves a significant amount of effort ["$$"] (e.g. for the introduction of new systems or processes or for a more detailed specification of the metric), or if the metric can be **usually** implemented with limited effort ["$"](e.g. little adaption of existing systems [e.g. for time tracking]).

[4] The rating for "Suitability of Metric" specifies how suitable/effective this metric is, with regard of tracking the effectiveness of R&D in software innovation [★☆☆☆☆ … very low; ★★★★★ … very high].

A. Input Metrics

i. __Ideas__

Ideas are an important input - the rocket fuel for innovation. Most companies do not have a shortage of ideas – although they might think so. But if they don't measure, they'll never know. And in case they do not have enough ideas, they should work on solving this issue.

Feasible metrics in this area include the following:

Number of raw ideas generated

Number or percentage of ideas that turn into successful new or improved products

Number of ideas generated and the expected payback for each

Number of ideas coming from (collaboration with) partners/customers

Number of individuals who contribute ideas to each successful new product

Number of ideas coming from other departments (Pre-Sales)

Tracking ideas can be relatively simple – in case there is already a process/system in place for collecting and managing ideas from employees/customers/partners. Doing so did pay off for many companies (Davila, et al., 2006) and should be definitely considered by any organization.

Most firms seem to capture, consolidate and manage ideas/requirements in a database (or spreadsheet at least), but hardly any organization integrated that into a stage-gate like innovation process.

ii. ***Learning Behavior***

"The SEI[5] estimates that more than 70 percent of the cost of developing software is attributable to personnel costs: the skills, experience and work habits of engineers, which largely determine the results of the software development process. It developed the Personal Software Process to help individual engineers improve their performance by bringing discipline to the way they develop software." (Barnett, et al., 2002)

This means that people – and their learning behavior – are at the very heart of innovation performance. Keeping an eye on learning behavior is therefore important, especially for organizations which are focused on improving the mid- to long-term effect on innovation performance.

Some aspects of learning behavior are tricky to measure, since hard facts are often not available for measurement/evaluation (yet).

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[5] Software Engineering Institute (Carnegie Mellon)

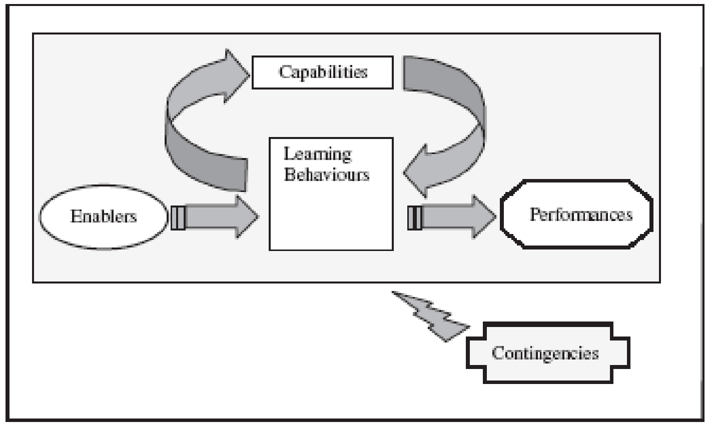

Figure 17. Elements in the CIMA Model for Learning in Product Innovation Processes (Gieskes, et al., 2004)

"*Learning behaviours* exhibited by individuals and by teams are the core elements that lead to a certain *performance*. These behaviours can be addressed through so-called *enablers*, managerial decisions and activities that do have an impact (but that not necessarily need to be aimed directly at improving learning behaviour). The identification of contingencies is required to take into account the uniqueness of product innovation processes and organizational differences. *Capabilities* (integrated stocks of resources that are accumulated over time through learning) are built through exercising the behaviours and, in turn, help building the learning behaviours. […]

The information-processing perspective provides a valuable means for categorizing different learning behaviours with regard to learning process:

Knowledge acquisition and generation: individuals and groups use innovation processes as opportunities to develop knowledge, use part of the available time and resources to experiment, and try to assimilate and to use knowledge from external sources. […]

Information distribution: individuals and groups integrate and transfer knowledge within and between all the different phases of product innovation processes, and throughout the organization. People analyse their experiences in order to identify knowledge and information that is really important and may be applied in other situations. […]

Information interpretation: people are aware of the value of sharing knowledge acquired in different product innovation processes. As such, individuals and groups use the strategic goals and objectives of a product innovation process to focus and prioritise their learning activities, that is to say, their behavior. […]

Information storage and retrieval: people embed knowledge and make it available to other people in the organization by incorporating it in vehicles such as reports, databases, and product and process standards that can be more widely disseminated and retained over time. […]" (Gieskes, et al., 2004)

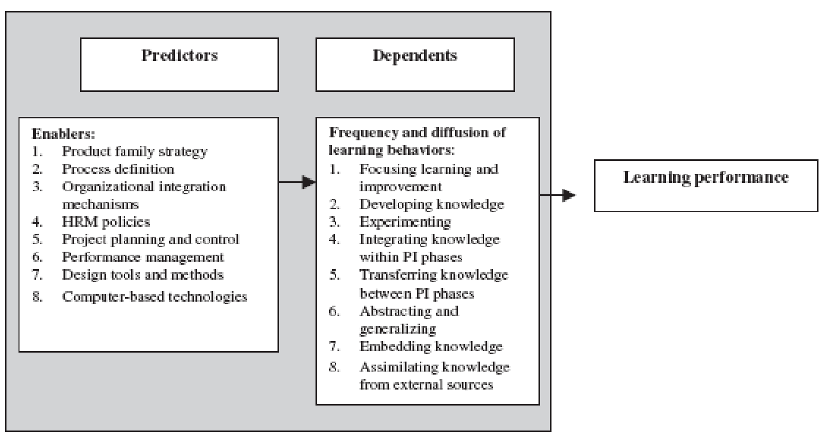

Figure 18. Measuring Learning Performance
(Gieskes, et al., 2004)

[Learning behavior] Frequency is a measure of how often the ***learning behavior*** is exhibited by individuals and groups (e.g. embed knowledge and make it available to other people in the organization by incorporating it in vehicles such as reports, databases…

[Learning behavior] Diffusion is a measure of how widespread the ***learning behavior*** is throughout the product innovation process.

Besides those metrics a number of other metrics can potentially be used to control the Input "Human Resources":

Individual networking skills

Quality of new recruits

Quality of recruiting process

Mix of backgrounds

B. Process Metrics

iii. Maintenance vs. New Functionality

I was discussing metrics and methods of measurement in the software industry with a number of colleagues in that field. The only metric that was relatively common was:

Percentage of work (days, FTEs) spent on maintenance tasks (versus new features/functionality)

This metric gives a very good indication about how much effort goes into "new" functionality. Depending on the type of software that is being developed most organizations seem to reach a score of roughly 50%.

This metric is relatively easy to implement, since most organizations track at least tasks (work packages) including effort and categorization (if the task is to implement a new feature or to do maintenance).

iv. Focus Factor

Discussions on internet forums of communities that promote the use of agile development processes proof, that some early adopters are already very much concerned about the measurement of their (mature) development process. They start defining their own metrics and share thoughts about them (van Puffelens, 2007):

Focus factor = Percentage of time that is used to work on the planned/estimated tasks/times (compensates for meetings, discussions, coaching... - which were not included in estimations)

Although this metric was brought up by the agile software development community, it is potentially also applicable in non-agile environments.

Depending on the time/effort tracking system/process of the organization, the focus factor should be relatively easy to implement. A more detailed specification of this metric might be required.

v. Velocity

Velocity (and average productivity) seems to be an interesting metric, since it also plays a major role in planning within Agile projects. But velocity is a relative measurement: It can show how a team progresses over time, but it cannot be used as a benchmark across companies, or even across projects within a single company. The reason is that there is no standard for the size of an individual story or unit of work (e.g. hours of work per standard story).

Velocity = number of units completed in an iteration

Average productivity = velocity / number of team members

*vi. **Actual vs. Estimate***

The following figure lists a number of metrics for Operational Excellence (BSC Perspective: Internal Processes)

Operational excellence	Goal	Objective	Candidate metrics
OE1	Project management	Improve project management's ability to deliver projects on time and on budget	• Days of work (effort, duration) • Costs (fully loaded labor, hardware, software, training, other) • Estimated versus actual task duration, effort, cost • Work effort distribution by phase • Percent of deliverables completed within + or – 10% of estimate
OE2	Productivity	Improve developers' productivity on new application and maintenance projects	• Rate of delivery of units of work (lines of code, function points, story points) • Average time on defect repair, by type of defect • Value derived from reuse (days saved, dollars saved) • Hand-offs between internal organizations
OE3	Quality	Improve quality of delivered application	• Defects found per X units of work (KSLOC, FP, SP) – by origination, status, priority, type (technical versus functional) • Percent of work (days, FTEs) spent on maintenance tasks • Code coverage % for unit testing • Cost of quality – training (prevention costs), review/inspection (days, cost), rework/retest (failure costs) – % of total project effort • Level of compliance with standards, frameworks, etc.

Figure 19. Forrester Research: Candidate Metrics for Operational Excellence (Barnett, 2005)

Project management metrics that seem to be often used focus on time and budget of the project:

Actual vs. Estimate (cost, days)

Percentage of projects on schedule

Work effort distribution by phase

Those project management related metrics are applicable for any project and do give a good performance estimation. Introducing those metrics should lead to improved planning and forecasting.

Implementation is dependent on if and which metrics are already commonly used within the projects across the whole organization. If proper project management governance principles are being used within the organization it should be relatively simple to acquire and compare such metrics.

vii. Time to Market

In big companies time to market is a key issue and materially affects product-life-cycle profits. The time between an idea and its introduction in the marketplace is an indication of efficiency. Long delays mean there's a problem in the innovation structure:

Time to market

This metric forces new-product development teams to focus on execution and not allow the 'nice-to-haves' to distract from the 'must-haves'.

"The future will only move faster as businesses are driven to release more custom products to market. Speed. Speed. Speed. Speed is critical as we design for local customers and access local technology, talent, and trends." Steve Paolini, HP Malaysia (Wyleczuk, 1998)

Implementation of a time to market metric requires a more detailed specification of that metric and a (e.g. stage-gate like) process that allows to track innovations from ideas until they are incorporated in a certain product.

However companies who are putting all their focus on speed should be careful to not compromise on quality! Therefore simply putting more work pressure on developers is typically not a useful technique to increase speed.

If the focus is on reducing the duration of the R&D process, other approaches (e.g. increase reuse, implement product platforms…) should be considered in addition:

"To speed our products to market, and to leverage technology, we must generate common product platforms and technologies that enable a variety of end user products while executing as virtual teams." Bill Buffington, HP Palo Alto, USA (Wyleczuk, 1998)

viii. Value Derived from Reuse

Re-inventing the wheel is common practice in many branches – so it is in Software R&D.

Therefore the following metric should deserve extra attention:

Value derived from reuse (days saved, dollars saved)

Well organized development teams should be able to leverage a lot of the work that has already been done. Object-orientation, software patterns, component libraries and other approaches allow for saving a lot of time for development.

Like many other metrics, also this metric has to be customized to reflect the specific situation of an organization (e.g. use of object-orientation, availability of component libraries…).

It can help to significantly increase efficiency by eliminating/reducing redundant work (e.g. to implement similar functionality twice for two different products). And by doing so, the organization would be able to free resources for implementing new capabilities.

Before introducing that metric an analysis should be performed, to find out about how much redundant work is being carried out within the entire organization.

ix. Value Derived from Open Source Software

Besides measuring internal reuse it should be considered to measure how much value was derived from Open Source Software (days/dollars that would have had to be invested to develop the required functionality in-house):

Value derived from using Open Source Software (days saved, dollars saved)

Please refer to "6. Open Innovation Networks in the Software Industry" in the previous chapter to find out about the rational for this metric.

Implementation requires effort estimations for functionality that is being gained by integrating Open Source Software. When doing this estimations additional efforts (e.g. for research, integration, legal) that are necessary to make use of Open Source Software should not be neglected.

x. Product Platform Effectiveness

Davila, et al., define product platform effectiveness as:

Derivate development cost (or time) / platform development cost (or time)

This measure impacts the effectiveness and efficiency of a product. Derivative products that are based on a shared platform can be developed quickly and with low investment. The lower the ratio the higher the leverage the development organization is getting out of the initial product platform.

There are obviously also drawbacks when making extensive use of product platforms (risk, dependency, limitations…), but in general product platforms are a good thing and development organizations should definitely aim to share as much assets and knowledge as possible.

Implementation of this metric is relatively simple as long as development efforts are tracked accordingly.

xi. Prototypes

"Encourage rapid prototyping. Organizations with the best innovation track records are open to new ideas and the possibility that they may not work. To push ideas forward, these organizations create prototypes" (Cameron, et al., 2008)

Especially in software it is sometimes hard to understand for customers or colleagues what an application will do for them before they actually are able to see it in a live environment. Using prototypes early in the design process helps to communicate more effectively and efficiently. It reduces risk and potentially encourages people outside development to bring in their ideas.

Number of virtual prototypes

Paper-based prototypes (or similar) can be considered as virtual prototypes in the software industry.

Number of physical prototypes

Physical prototypes typically show the look-and-feel and potentially some key features.

Prototyping also supports other methods to foster innovation – including their metrics:

Number of "what-if" scenarios explored per new product

Implementation of those metrics is relatively simple. But the benefit of prototyping cannot be realized by introducing only the metric. Like with some of the other process metrics, behavioral changes are required – which leads to additional efforts for management of change (e.g. training and communication).

C. Output Metrics

xii. Unique Selling Points (USPs)

The CTO of a very successful software company mentioned an interesting metric they are using (amongst others) to govern Roadmap development:

USPs (Unique Selling Points/Proposition) per product

The USP needs to be a recognized and valued USP (by the customer) on all markets the product is positioned in. Every major release has to deliver at least one new USP. Their key product currently features about 4 USPs.

I think this metric is a very effective one, since it is focused factors that drive their buying decision. Furthermore it requires tight collaboration between R&D and Marketing. And it drives prioritization efforts transparently and directly.

This metric should be relatively easy to implement.

xiii. Measuring Development in Business Terms(/Value)

In general project viability should be judged before implementation begins. This is true for any commercial application or custom business application:

high-level estimate of overall costs (usually days) versus the estimated business value that the system is expected to deliver

Commercial software firms are pretty mature in managing their portfolio and they usually forecast the business value (license revenue) a new product is going to deliver and compare it with a high-level estimate of overall development costs.

They are also good with prioritization during development – which is very much focused on requirements. But the prioritization of those requirements does often not reflect its business value. To overcome this, a relative measure of business value could be added to each requirement:

business value of requirement

For example, a requirement expected to deliver four times as much business value as another would be rated "4X." Requirements can then be numerically ranked according to their relative benefits. This ranking should drive the order in which requirements are developed. The sum of all the requirements' relative values gives a total relative value for the project.

Another approach is to assign a relative monetary value to the requirements (say, $0.25 up to $100) based on the customer's (and/or Marketing's) input. Some business people are more comfortable working with relative financial values rather than just a generic relative ratio. (Barnett, 2005)

Using business value for requirement prioritization is definitely a good idea.

But the applicability of such metrics to evaluate the overall effectiveness and efficiency of Software R&D is limited and would require a lot of effort for more detailed specification and execution governance.

Approaches like SCRaP might be more specific and therefore better applicable.

xiv. ***SCRaP***

Enterprise Software is used to gain competitive advantage. An interesting view would therefore be to measure the business benefit customers can obtain when using software.

Like some similar work that has been carried out for the general use of IT in the production industry:

"Most empirical researchers investigating the returns to IT investments have focused on gains in certain measures of productivity, though well aware that they are likely to be underestimating the total returns to IT investments. Testing this proposition requires the collection of unique data – data that identifies what IT really means in the context of the production process, data on the productivity gains from IT at the process level, and data on product customization." (Bartel, et al., 2005)

This evaluation of the 'return on IT investment' should be carried out for any Enterprise Software product. Needless to say that this can be a complex task with many variables, but there are feasible approaches available which could also be applied:

"Our project is also concerned with a second specific measure, that of the increase in competitive advantage that an innovation has achieved. We are studying technological investments in firms, and we start from the position that the investing firm/SBU[6] has assumed that these investments will result in competitive advantage gain. The gain can, in turn, be attributed in part to the

[6] Strategic Business Unit

decision to make the technological investment, in part to the way in which the managers adjusted the business processes which surround the new technological investment, and in part to the inherent technical efficacy of the new machine (or process) which is going into operation.

In our project, the measure of competitive advantage is obtained by what we have called SCRaP analysis; Speed, Cost, Reliability and Preparedness. This measures the extent to which the customers or clients of the company benefit because of the new investment in terms of the speed which they obtain the service or product they are seeking, the cost they have to pay out to obtain a 'unit' of that service or product they are seeking, and the reliability of the service to the customer. When these items are measured, it is usually possible to obtain an estimate of the overall competitive advantage gained, by comparing the new performance figures for the company with the best performer in the market and with the market average." (McCosh, et al., 1998)

So this is basically a more sophisticated way of evaluating the Return on Investment that the customer experiences when using the product/solution.

It might require some effort to figure out, normalize and proof the Return on Investment, but it puts the focus directly on the customers buying decisions.

xv. *Patents*

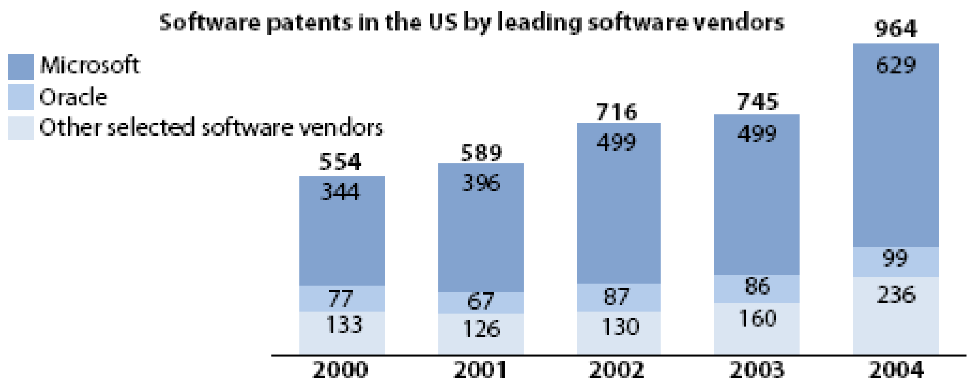

Figure 20. Forrester Research: Software Patenting is On The Rise (Bartels, et al., 2006)

The number of patents filed is continuously increasing (at least in the US, where patent law is slightly different from most European countries as far as software patents are concerned).

Patents are important to protect intellectual property and to form a barrier for others to enter the market. But are they a good measure for "innovativeness"?

Patents do not necessary lead to a successful innovation. But inventions are the basis for innovations. Therefore patent-related metrics have some (limited) explanatory power:

Number of patents filed

Value of software patents

Well established software vendors should treat those metrics with care, but for start-up companies it is typically a good thing to focus on filing patents:

"The software sector is characterized by low tangible assets and high intangible assets, which means that it is more important to have intellectual property rights in order to secure funding for investment." (Hall, et al., 2006)

13. INNOVATION COMPASS

Besides the outlined metrics, some new methodologies to evaluate the "innovativeness" of organization are arising. They are still not very mature yet, but worthwhile to mention.

One such way to measure R&D organizations – as part of the new product development process – is a self-audit tool as described by Radnor and Noke (Radnor, et al., 2002).

This diagnostic tool is being referred to as the 'innovation compass' and uses self-audit methodology to identify gaps between current and desired performance of individual organizations.

The compass comprises of five core themes:

- structure
- leadership
- output
- teams
- context

It combines quantitative and qualitative techniques and allows for benchmarking.

Before this compass can be effectively used on a broader basis, additional case studies (cross case and statistical analysis) will be required and further research is necessary to:

- identify ‘critical factors’ which would be important for organizations to address

- identify relationships between the various factors

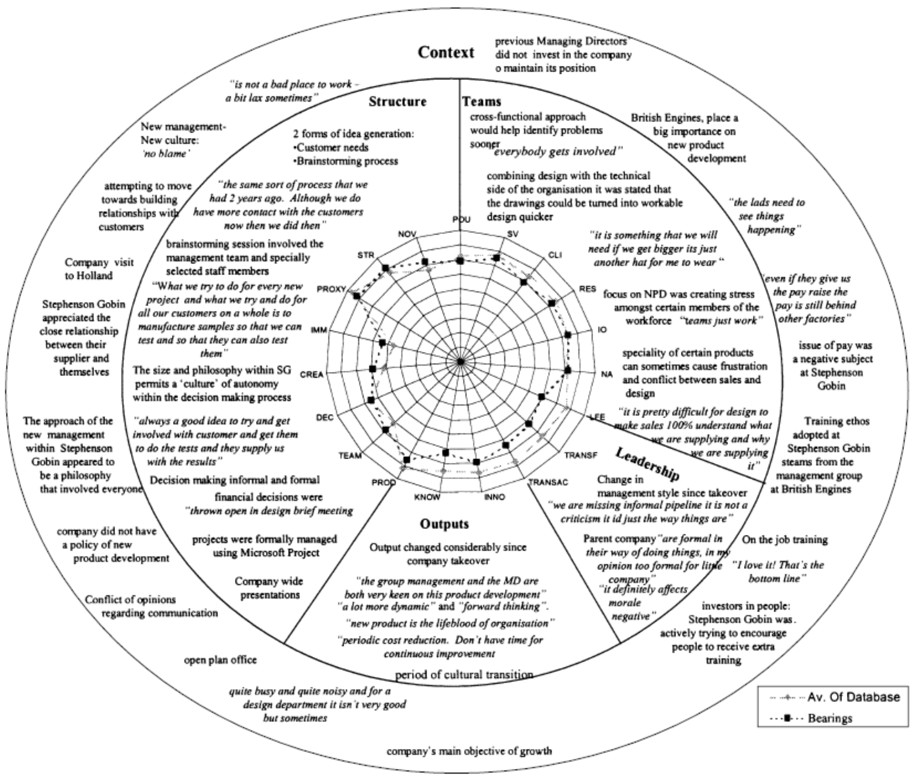

Figure 21. A Populated Compass for Bearings (Radnor, et al., 2002)

Although it might take a while until approaches like this become widely spread, their evolution should be watched carefully. Especially because it could provide a solid foundation for benchmarking:

“By benchmarking the practices and processes of innovation with other organizations, companies may be able not only ‘to adapt’ but also ‘advance’ in an ever-more competitive marketplace.” (Radnor, et al., 2000)

14. GENERAL BEST PRACTICES

Every book, report or marketing paper in that field contains a number of good and best practices. Davila (Davila, et al., 2006) summarizes some of the most essential ones:

Directly link the innovation measures to the innovation strategy and the innovation business model. The majority of global companies surveyed recognized that they were deficient in measuring the strategic value of their innovation.

Don't be rigid; build in enough variability to allow valuable measurement. Different innovation processes and different organizational levels need different measurement systems, and these can vary over time. Projects need measures that are consistent with the business unit but different enough to capture project-specific innovation characteristics. The measures that are appropriate at the beginning of a project may not be adequate in later stages.

Know the specific purpose of each type of measurement system; trying to achieve too many objectives will get you nowhere. Dissect measurement systems to ensure that they are providing the right mix of planning, monitoring, and learning.

Keep it simple; too many measures can be more of a distraction than a help. It is better to have five simple measures linked to the strategy and innovation business model than 20-30 measures; even if the additional measures provide a more complete picture, they will overwhelm the decision-makers. In this case, quantity is the enemy of quality.

Stay in charge. Be aware of the limitations of measurement systems. They enhance but not replace good management.

15. BALANCED SCORECARD

Performance measures are a common control mechanism. They communicate desired outcomes or behavior to employees and are used to evaluate success in achieving goals. It is generally believed that the best performance measures are those linked to a firm's strategy (Kaplan, et al., 2001). Innovation performance measures are most appropriate when they are related to strategy. However strategy does not seem to guides the selection of Innovation performance measures in practice yet.

Some software development organizations already use performance management frameworks – which are likely to be embedded in corporate performance management frameworks. The Balanced Scorecard – as defined by Kaplan and Norton (Kaplan, et al., 2001) – is the basis for most of them.

And besides company-wide scorecard systems, business units sometimes have their own scorecards. Like the one below, suggested by Liz Barnett from Forrester. She adapted the Title, the Mission and the Objectives of the four perspectives to reflect the requirements of Application Development organizations.

Mature organizations should implement scorecards like this to closely align their operation with their strategy.

Operational excellence *How does management measure a development organization's effectiveness?* Mission: To deliver timely and effective application development and integration projects at or under budget and service-level agreements. Objectives: • Project management • Productivity and effectiveness of the organization • Quality	**User orientation** *How effective is the team in meeting the users' needs?* Mission: To be the supplier of choice for all application development and integration initiatives. Objectives: • User satisfaction • Responsiveness to business needs • Service-level performance • IT business partnership
Business value *How do application development projects contribute (directly or indirectly) to quantitative business benefits?* Mission: To enable and contribute to the attainment of business strategies through the effective use of software development teams and projects. Objectives: • Business value of AD projects • Alignment of AD projects to business strategy • Synergies across business units to leverage resources	**Future orientation** *How will changes to development processes affect the organization's ability to deliver value and quality in the future?* Mission: To develop internal capabilities to learn and innovate to exploit future opportunities. Objectives: • Development capability improvement • Use of emerging methodologies and processes • Skills for future needs

Figure 22. Forrester Research: The Balanced Scorecard Model for Application Development Metrics (Barnett, 2005)

16. RADICAL VERSUS INCREMENTAL INNOVATION

Innovation strategy defines how much focus should be put on radical (break-through) innovation versus incremental innovation. This decision has also got a major influence on goals setting and it also impacts which metrics are applicable.

The importance of technology (and therefore Software R&D [High Technology]) in innovation is particularly high with *radical* innovations which address *new markets.*

Innovation	Technology	Market	Importance of		
			Market	Technology	Organisation
Incremental	Low	Existing	3	3	1
Incremental	Low	New	3	3	1
Incremental	High	Existing	3	2	3
Incremental	High	New	2	2	3
Radical	Low	Existing	2	2	2
Radical	Low	New	1	2	2
Radical	High	Existing	2	2	3
Radical	High	New	1	3	3

Note: 1=less important, 2=important, and 3=very important

Figure 23. Incremental versus Radical Innovation (McCosh, et al., 1998)

17. COMPOUND MEASUREMENT – MULTIPLE METRICS

Most organizations realized that measuring innovation performance cannot be performed by the mean of one single metric only.

"Concerning the measurement of innovative activity, Johannessen et al (2001, pp. 22-23) warn against the use of 'proxies'. They are critical of the use of measures like total R&D expenditures, relative R&D expenditures, number of patents, number of innovations, number of new product and service introductions. And indeed, the reasons given for rejecting each individual measure are convincing. For example, not every innovation can be patented, and innovations that can are not always patented.

Still it is desirable to have an instrument, however imperfect, that allows external assessment of creativity, because the criteria in internal (team or organization) assessment of creativity, and the rigor of their use, may vary considerably between teams and between organizations. It may be possible to develop a measure that comprises a wide variety of indicators (e.g. Research proposals written, papers published, designs produced, products designed, presentations made, patents received, awards won, projects completed, see Brown & Svenson, 1998). In addition, measures to capture internal assessment (and criteria used for that) can be used. Here, an additional instrument would be useful to control for 'degree of mildness in judgment'." (Vissers, et al., 2002)

Effective measurement combines a (small) number of metrics, ideally combining:

- Input, Process and Output metrics
- Qualitative and quantitative metrics
- External and internal metric
- Financial and non-financial metrics

Most firms that measure performance seem to use a combination of financial and non-financial measures. Such combinations are used in a variety of settings and are generally agreed to be most appropriate for performance measurement. The reason for this is that the performance of R&D functions are difficult to measure financially – because of the long-term nature of the work and the lag between Innovation/R&D work and financial performance on the market.

"In an empirical study of R&D management controls, Rockness and Shields (1988) found that financial measures were less useful in evaluation and in determining rewards than in planning and monitoring activities. Additionally, identifying individual members' contributions to NPD team financial outcomes is difficult (Milgrom and Roberts 1992). These factors may partially explain why NPD managers prefer nonfinancial performance measures that more directly assess critical strategic dimensions such as customer satisfaction, time to market, and product quality (Hertenstein and Platt 1997). We expect NPD results to be assessed in both financial and nonfinancial terms. However, we expect NPD managers to want increased emphasis on nonfinancial measures and decreased emphasis on financial measures due to the lag between NPD work and product launch and to the difficulty in separating NPD financial results from those of other functions such as marketing or manufacturing. Further, because Cooper (1984a, 1984b) and more recently Griffin (1997) report that strategic guidance is an important determinant of success for NPD projects, we expect NPD managers to perceive a fit between the firm's strategy and the performance measures that the firm emphasizes." (Performance Measures and Management Control in New Product Development, 2000)

18. CONCLUSION

It seems as if measurement is one of the most significant factors in successful innovation. But at the same time it is still one of the least attended to, especially in software firms.

But since organizations realize that they cannot grow through cost reduction or reengineering alone, innovation is considered to be the key element in providing aggressive top-line growth, and for increasing bottom-line results.

Senior managers who are putting a focus on innovation management should make innovation metrics an integral part of their corporate performance management frameworks.

Although there is no common set of measures, Chapter III (12. Collection of Metrics) describes some metrics that address the typical goals of many Software R&D organizations (increase "innovativeness"; reduce cost for R&D; reduce duration of R&D process; expand product lifecycle).

It heavily depends on the strategy of the organization which metrics should be chosen and how they should be implemented, since the metrics and objectives should reflect the culture, organizational maturity, vision, mission and goals of the organization.

And because measuring innovation performance cannot be performed by the mean of one single metric only, a (small) number of metrics should be combined to form a compound innovation measurement solution.

Since all metrics rely on accurate data, some of them might depend on the availability and maturity of certain processes (or their underlying systems). One fact that becomes very apparent in that regard is that

- the innovation management process (stage-gate; innovation pipeline) and
- the software development process

are typically <u>not</u> very well formalized and integrated ("Idea-to-Cash") yet.

By formalizing and integrating the two (e.g. using Project- and Portfolio Management software), organizations would be able to automatically track more relevant measures (ideas, requirements, efforts…) and by doing so benefit from more transparency and better control.

Furthermore this would foster learning behavior, as the definition and standardization of the innovation process is positively related to learning behavior. (Gieskes, et al., 2004)

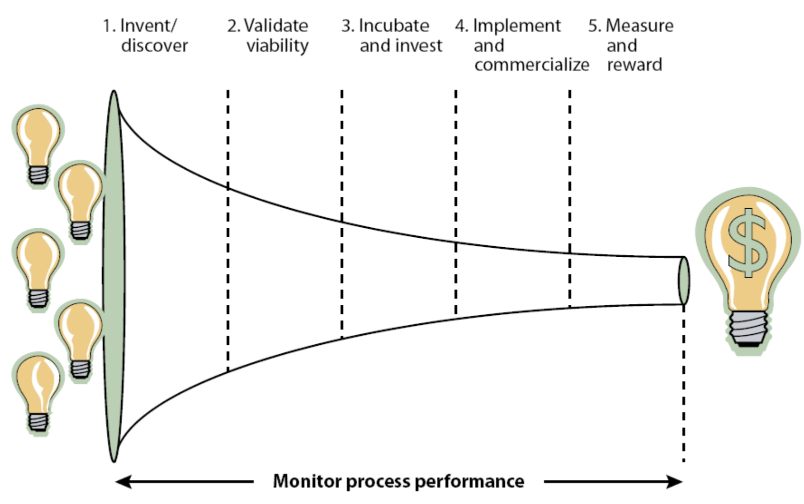

Figure 24. Forrester Research: The Innovation Pipeline Process (Cameron, et al., 2008)

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APPENDIX

More than 250 metrics which were potentially relevant for this document have been discovered during the work on this master thesis. The following table summarizes those metrics.

Metric	Input /Process /Output	Source	Comment	Categorization (taken from source)	Balanced Scorecard Perspective (taken from source)
Time to market	Process	(Andrew, et al., 2006)	Speed to market is as important as getting there with the right products. This is a critical metric for driving cross-functional interaction.		
New product sales	Output	(Andrew, et al., 2006)	An easy-to-measure metric with the most direct impact on the business. In general, new products are much more profitable than old ones, so if they sell well the objective is achieved.		
Return on investment	Output/ Input	(Andrew, et al., 2006)	Innovation is an investment with high costs. It should be expected to have a return.		

Financial resources being committed	Input	(Andrew, et al., 2006)	Every company measures this, in one form or another. But achieving and maintaining clarity over time, and using this understanding to actively manage the financial profile of an innovation, is much less common.		
People committed (how many and how they are utilized)	Input	(Andrew, et al., 2007)	You need to track the total number of people committed to an innovation, certainly. But you also, more importantly, need to monitor how your key people are being used. Every company has individuals or small groups that are highly sought after and disproportionally valuable - everyone wants them on his/her project.		
Number of raw ideas generated	Input	(Rugullies, 2002)	Ideas are an important input - the rocket fuel for innovation. While many companies think they have a shortage of ideas, most don't. But if you don't measure, you'll never know. And if it turns out that you really don't have enough big ideas, you'll need to know that in order to put in place the necessary steps to resolve the shortfalls.		
Number or percentage of ideas that turn into successful new or improved products	Input	(Rugullies, 2002)			

Number of ideas generated and the expected payback for each	Input	(Andrew, et al., 2006)			
Number of ideas coming from (collaboration with) partners					
Number of ideas coming from (collaboration with) customers					
External verification score	Process	(Mosimann, et al., 2007)			
Idea added-value score	Process	(Mosimann, et al., 2007)			
Number of ideas coming from other departments (Pre-Sales)					
Number of individuals who contribute ideas to each successful new product	Input	(Rugullies, 2002)			
Number of duplicate and complementary ideas submitted	Input	(Rugullies, 2002)			
Number of "what-if" scenarios explored per new product	Input	(Rugullies, 2002)			

Frequency of design meetings	Input	(Rugullies, 2002)			
Number of virtual prototypes	Input	(Rugullies, 2002)			
Number of physical prototypes	Input	(Rugullies, 2002)			
Operating expenses	Input	(Andrew, et al., 2007)			
Capital expenditures	Input	(Andrew, et al., 2007)			
Key capabilities (such as IT, manufacturing and tooling) and how they are utilized	Input	(Andrew, et al., 2007)	What and where are the shared resources - and potential bottlenecks - in your organization? For many companies, especially in the financial services industry, it is parts of the IT infrastructure. Regardless of what and where these happen to be in your organization, you need to know how they are being used to support innovation currently as well as how they could be used.		
Level of business knowledge within IT	Input	(Symons, 2007)	e.g. % of staff who attended MBA class, # of staff in rotation role		
Acquisition of technology from others (e.g. patents, licenses)	Input	(Rogers, 1998)			
Training expenditures relating to new/changed products/processes	Input	(Rogers, 1998)			

Resources expended per individual project and on average	Process	(Andrew, et al., 2006)	A process needs to be both effective and efficient. Most companies can readily measure efficiency, so you can start there - but don't stop there		
Cycle times for the entire process and specific parts	Process	(Andrew, et al., 2006)	Speed to market can have a determining influence on how much cash an innovation ultimately generates. You need to track how long it takes to get ideas turned into offerings, and ultimately into cash. If you don't have a robust time to market measurement, ask yourself why.		
The number of ideas that are moving from one stage of the process to the next	Process	(Andrew, et al., 2006)	If a process is supposed to be working, is it working? What is happening inside the process at any point in time?		
The difference between the initial expected value of an idea and the actual realized value.	Process	(Andrew, et al., 2006)	The expected payback from an idea is the basis for many of the most important decisions a leader will make regarding that idea. A key item to understand - and measure, therefore - is how well your process does at estimating expected returns versus the returns actually generated.		
Resource efficiency (average and over time)	Process	(Andrew, et al., 2007)			
Actual versus planned time to market	Process	(Andrew, et al., 2007)			
Kill rates by stage	Process	(Andrew, et al., 2007)			

Actual versus expected process performance	Process	(Andrew, et al., 2007)			
Milestone compliance	Process	(Andrew, et al., 2007)			
Number of suppliers and partners involved	Process	(Andrew, et al., 2007)			
The number of new products or services launched	Output	(Andrew, et al., 2006)	While the absolute number of new offerings is not a financial output, you need to know what is coming out at the end of the process.		
Actual versus projected incremental revenues and profits	Output	(Andrew, et al., 2007)			
Cannibalization of existing product sales by new products	Output	(Andrew, et al., 2006)	Cannibalization is one of the dirty secrets of innovation. Few companies measure it well or even really consider it. And what about the cost of not cannibalizing your old products? Most companies don't even ask that question.		
ROI of innovation spending	Output	(Andrew, et al., 2007)	This is, ultimately, what it's all about. Are you earning a sufficient return on your innovation spending? Today only about 50% of companies think they are; a far smaller number truly know what their return is. Innovation ROI is a key metric to use to determine how much to invest in innovation - and ultimately a determinant of the company's stock price and total shareholder return.		
Market share growth	Output	(Andrew, et al., 2007)			

New-product success rates	Output	(Andrew, et al., 2007)			
Number of new customers	Output	(Andrew, et al., 2007)			
Rate of customer adoption	Output	(Andrew, et al., 2007)			
New-product attrition rates	Output	(Andrew, et al., 2007)			
Percentage of targeted market reached	Output	(Andrew, et al., 2007)			
Product quality	Output	(Andrew, et al., 2007)			
Payback period	Output	(Andrew, et al., 2007)			
Number of patents filed	Output	(Andrew, et al., 2007)	Does not necessarily represent a commercialization of ideas.		
Value of software patents	Output	(Hall, et al., 2006)	Does not necessarily represent a commercialization of ideas.		
Number of publications written by staff	Output	(Andrew, et al., 2007)	Does not necessarily represent a commercialization of ideas.		
Intellectual property statistics	Output	(Rogers, 1998)	Includes trade mark and design applications and grants. Does not necessarily represent a commercialization of ideas.		
Brand strength (third party rankings)	Output	(Andrew, et al., 2007)			
Employee satisfaction (based on surveys)	Output	(Andrew, et al., 2007)			

Ecosystem strength (based on interviews)	Output	(Andrew, et al., 2007)			
Product/ service satisfaction ratings	Output	(Haven, 2007)			
Number of USPs	Output		USP = Unique Selling Point/Proposition		
Mix of backgrounds	Input	(Davila, et al., 2006)		Ideation/ Culture	
Quality of new recruits	Input	(Davila, et al., 2006)		Ideation/ Culture	
Staff motivation	Input	(Davila, et al., 2006)		Ideation/ Culture	
Research agreements with partners	Input	(Davila, et al., 2006)		Ideation/ Interaction	
Percentage of budget that is non-internal	Input	(Davila, et al., 2006)		Ideation/ Interaction	
Quality of IT infrastructur e to support interest groups	Input	(Davila, et al., 2006)		Ideation/ Interaction	
Individual networking skills	Input	(Davila, et al., 2006)		Ideation/ Interaction	
Knowledge depth	Input	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	
Quality of resource allocation process	Input	(Davila, et al., 2006)		Ideation/ Process and Systems	
Quality of recruiting process	Input	(Davila, et al., 2006)		Ideation/ Process and Systems	
Effectiveness of motivational systems	Input	(Davila, et al., 2006)		Ideation/ Process and Systems	

Empower-ment	Input	(Davila, et al., 2006)		Ideation/ Process and Systems	
Training sessions	Process	(Davila, et al., 2006)		Ideation/ Culture	
Communication efforts	Process	(Davila, et al., 2006)		Ideation/ Culture	
Number of ideas from planning exercise	Process	(Davila, et al., 2006)		Ideation/ Culture	
Innovation and creativity workshops	Process	(Davila, et al., 2006)		Ideation/ Interaction	
Ideas fairs	Process	(Davila, et al., 2006)		Ideation/ Interaction	
Conference attendance	Process	(Davila, et al., 2006)		Ideation/ Interaction	
Interest groups	Process	(Davila, et al., 2006)		Ideation/Interaction	
Participation of suppliers in stage-gate process	Process	(Davila, et al., 2006)		Ideation/ Interaction	
Number of contacts with partners	Process	(Davila, et al., 2006)		Ideation/ Interaction	
Communication workshops	Process	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	
Competitive information	Process	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	
Quality of development pipeline	Process	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	
Quality of training programs	Process	(Davila, et al., 2006)		Ideation/ Process and Systems	
Quality of workshops	Process	(Davila, et al., 2006)		Ideation/ Process and Systems	
Quality fo external collaboration	Process	(Davila, et al., 2006)		Ideation/ Process and Systems	

Quality of planning systems	Process	(Davila, et al., 2006)		Ideation/ Process and Systems	
R&D staff turnover	Outputs	(Davila, et al., 2006)		Ideation/ Culture	
Employee suggestions	Outputs	(Davila, et al., 2006)		Ideation/ Culture	
Employee commit-ments	Outputs	(Davila, et al., 2006)		Ideation/ Culture	
External HR audits	Outputs	(Davila, et al., 2006)		Ideation/ Culture	
Change in core compe-tencies	Outputs	(Davila, et al., 2006)		Ideation/ Culture	
Quality of ideas funded	Outputs	(Davila, et al., 2006)		Ideation/ Interaction	
Alliances to further develop ideas	Outputs	(Davila, et al., 2006)		Ideation/ Interaction	
Investements in new projects	Outputs	(Davila, et al., 2006)		Ideation/ Interaction	
Number of ideas from outside R&D	Outputs	(Davila, et al., 2006)		Ideation/ Interaction	
Deal options that are exercised	Outputs	(Davila, et al., 2006)		Ideation/ Interaction	
Assessment of competitors' innovation investments	Outputs	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	
Map of upcoming innovations to the market	Outputs	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	
Under-standing of company strategy	Outputs	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	

Percentage of growth covered by innovations	Outputs	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	
Funds committed to innovation	Outputs	(Davila, et al., 2006)		Ideation/ Process and Systems	
Effectiveness of planning systems	Outputs	(Davila, et al., 2006)		Ideation/ Process and Systems	
Improvement of knowledge stock	Outputs	(Davila, et al., 2006)		Ideation/ Process and Systems	
Cost of misbehavior	Output/ Outcome	(Davila, et al., 2006)		Ideation/ Culture	
Change in revenue per employee	Output/ Outcome	(Davila, et al., 2006)		Ideation/ Culture	
Percentage of sales together with partners	Output/ Outcome	(Davila, et al., 2006)		Ideation/ Interaction	
Percentage of sales from ideas originated outside	Output/ Outcome	(Davila, et al., 2006)		Ideation/ Interaction	
Expected sales from incremental innovations against competitors	Output/ Outcome	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	
Expected sales from radical innovations against competitors	Output/ Outcome	(Davila, et al., 2006)		Ideation/ Understanding of Strategy	

Cost of developing and maintaining infra-structure	Output/ Outcome	(Davila, et al., 2006)		Ideation/ Process and Systems	
Actual versus budgeted cost for planning and knowledge management	Output/ Outcome	(Davila, et al., 2006)		Ideation/ Process and Systems	
Derivative development cost (or time) / platform development cost (or time)	Process	(Davila, et al., 2006)		Commitment and focus on innovation	
Time dedicated to innovation	Input	(Davila, et al., 2006)		Commitment and focus on innovation	
Budget percent allocated to innovation efforts	Input	(Davila, et al., 2006)		Commitment and focus on innovation	
Performance-based compensation linked to innovation success	Input	(Davila, et al., 2006)		Commitment and focus on innovation	
Success of ideas passing through selection and execution processes	Input	(Davila, et al., 2006)		Commitment and focus on innovation	
Investment in training	Input	(Davila, et al., 2006)		Commitment and focus on innovation	

Level of innovation integration across business units and functions	Input	(Davila, et al., 2006)		Balanced innovation of networks inside and outside of organization	
Mix of innovation sources	Input	(Davila, et al., 2006)		Balanced innovation of networks inside and outside of organization	
Percentage of innovation projects outsourced	Input	(Davila, et al., 2006)		Balanced innovation of networks inside and outside of organization	
Number of strategic allicances	Input	(Davila, et al., 2006)		Balanced innovation of networks inside and outside of organization	
Number of experienced innovation team members	Input	(Davila, et al., 2006)		Balanced innovation of networks inside and outside of organization	
Assessment of supplier capabilities	Input	(Davila, et al., 2006)		Balanced innovation of networks inside and outside of organization	
Number, cost, price, and perception of new products offered from innovation projects	Input	(Davila, et al., 2006)		Coherent and aligned innovation strategy	

Number, cost, price, and perception of new services offered from innovation projects	Input	(Davila, et al., 2006)		Coherent and aligned innovation strategy	
Perception of brand	Input	(Davila, et al., 2006)		Coherent and aligned innovation strategy	
Profitability of innovation operations	Input	(Davila, et al., 2006)		Coherent and aligned innovation strategy	
Objectives for innovation efforts clearly communicated to senior managers and employees	Input	(Davila, et al., 2006)		Coherent and aligned innovation strategy	
Competitive position within industry	Input	(Davila, et al., 2006)		Coherent and aligned innovation strategy	
Number, complexity and size of competitors, customers, partners, and suppliers	Input	(Davila, et al., 2006)		Coherent and aligned innovation strategy	

Percentage of performance measures and rewards aligned and linked to innovation activities	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Quality of IT infra-structure	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Quality of information for innovation	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Market and technology research resources	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Amount and quality of customer data acquired related to innovation	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Dollars of resources available for innovation	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Free time allowances for R&D employees	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	

Geographic diversity of production and sales	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Level of empowerment to Strategic Business Unit (SBU) and functional managers	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Cross-functional initiatives	Input	(Davila, et al., 2006)		Appropriate management infrastructure for effective innovation implementation	
Percentage of innovation efforts devoted to radical, semi-radical, and incremental innovation	Process	(Davila, et al., 2006)		Portfolio	
Portfolio balanced over time, returns, risk, and technologies	Process	(Davila, et al., 2006)		Portfolio	
Alignment between innovation strategy and resource allocation	Process	(Davila, et al., 2006)		Portfolio	
Product platform effectiveness	Process	(Davila, et al., 2006)		Execution	

Reduction in new product/process development time/cost	Process	(Davila, et al., 2006)		Execution	
Within target sales/profits	Process	(Davila, et al., 2006)		Execution	
Projected within time, budget, product performance targets	Process	(Davila, et al., 2006)		Execution	
R&D productivity	Process	(Davila, et al., 2006)		Execution	
Number of new patents granted each year	Process	(Davila, et al., 2006)		Execution	
Number of gateway returns	Process	(Davila, et al., 2006)		Execution	
Rate and quality of experimentation	Process	(Davila, et al., 2006)		Execution	
Cost, development time, delivery time, quantity, and price of products and services offered	Process	(Davila, et al., 2006)		Execution	
Product and process quality score	Process	(Davila, et al., 2006)		Execution	
New customers gained through innovation	Output/ Outcome	(Davila, et al., 2006)		Customer acquisition	

Number of customers through existing products/services who buy new products/services	Output/ Outcome	(Davila, et al., 2006)		Customer acquisition	
Number of new customers of new products/services who go on to buy existing products/services	Output/ Outcome	(Davila, et al., 2006)		Customer acquisition	
Market share	Output/ Outcome	(Davila, et al., 2006)		Customer acquisition	
Frequency of repeat customers	Output/ Outcome	(Davila, et al., 2006)		Customer loyalty	
Average annual sales per customer	Output/ Outcome	(Davila, et al., 2006)		Customer loyalty	
Customer satisfaction with innovation activities	Output/ Outcome	(Davila, et al., 2006)		Customer loyalty	
Percentage of customer attrition	Output/ Outcome	(Davila, et al., 2006)		Customer loyalty	
Ratio of new visitors to repeat visitors	Output/ Outcome	(Davila, et al., 2006)		Customer loyalty	
Margin of product and services offered to customers	Output/ Outcome	(Davila, et al., 2006)		Value capture	

Average of prices paid by customers	Output/ Outcome	(Davila, et al., 2006)		Value capture	
Number of new product and service lines introduced	Output/ Outcome	(Davila, et al., 2006)		Value capture	
Profitability of innovation operations	Output/ Outcome	(Davila, et al., 2006)		Value capture	
Revenues generated through innovation efforts (total revenue, innovation revenue, revenue per innovation customer)	Output/ Outcome	(Davila, et al., 2006)		Value capture	
Customer profitability	Output/ Outcome	(Davila, et al., 2006)		Value capture	
Stock price	Output	(Davila, et al., 2006)		Long-term corporate profitability	
Projected sales growth	Output	(Davila, et al., 2006)		Long-term corporate profitability	
Projected residual income	Output	(Davila, et al., 2006)		Long-term corporate profitability	
Residual income growth	Output	(Davila, et al., 2006)		Short-term corporate profitability	
Sales growth	Output	(Davila, et al., 2006)		Short-term corporate profitability	
Return on equity	Output	(Davila, et al., 2006)		Short-term corporate profitability	

Percentage of sales from new products	Output	(Davila, et al., 2006)		Short-term corporate profitability	
Work effort distribution by phase	Process	(Barnett, 2005)			Internal Processes (Operational Excellence)
Rate of delivery of units of work (lines of code, function points, story points)	Output	(Barnett, 2005)			Internal Processes (Operational Excellence)
Average time on defect repair, by type of defect	Process	(Barnett, 2005)			Internal Processes (Operational Excellence)
Value derived from reuse (days saved, dollars saved)	Process	(Barnett, 2005)			Internal Processes (Operational Excellence)
Hand-offs between internal organizations	Process	(Barnett, 2005)			Internal Processes (Operational Excellence)
Defects found per X units of work (KSLOC, FP, SP) - by origination, status, priority, type (technical versus functional)	Process	(Barnett, 2005)	KSLOC = 1000 lines of code		Internal Processes (Operational Excellence)
Percentage of work (days, FTEs) spent on maintenance tasks	Process	(Barnett, 2005)	effort for new features vs. bugfixes/maintenance		Internal Processes (Operational Excellence)

Code coverage % for unit testing	Process	(Barnett, 2005)			Internal Processes (Operational Excellence)
Cost of quality - training (prevention costs), review/inspection (days, cost), rework/retest (failure costs) - % of total project effort	Process	(Barnett, 2005)			Internal Processes (Operational Excellence)
Level of compliance with standards, frameworks, etc.	Process	(Barnett, 2005)			Internal Processes (Operational Excellence)
Business value or NPV	Output	(Barnett, 2005)			Financial (Business Value)
Revenue, customer, or other business-specific increases	Output	(Barnett, 2005)			Financial (Business Value)
Percent of AD staff with personal development plans	Input	(Barnett, 2005)			Learning and Growth (Future Orientation)
Percent of AD staff meeting or exceeding competency standards for their position	Input	(Barnett, 2005)			Learning and Growth (Future Orientation)

Retention rates by performance level	Input	(Barnett, 2005)			Learning and Growth (Future Orientation)
Percentage of AD budget dedicated to research	Input	(Barnett, 2005)			Learning and Growth (Future Orientation)
Days budgeted/spent on mentoring	Input	(Barnett, 2005)			Learning and Growth (Future Orientation)
Days and dollars budgeted for recruiting	Input	(Barnett, 2005)			Learning and Growth (Future Orientation)
Ratio of in-house staff to contractors	Input	(Barnett, 2005)			Learning and Growth (Future Orientation)
Budget allocated to funding new roles	Input	(Barnett, 2005)			Learning and Growth (Future Orientation)
User satisfaction	Output	(Barnett, 2005)	e.g. responsiveness to business needs		Customer (User orientation)
Time spent together with customer per phase	Process	(Wecht, 2005)			
Mean time to repair or maintenance hours per installed function point	Process	(Barnett, et al., 2002)			
Mean time between defects	Process	(Barnett, et al., 2002)			

Percentage of testing time actually spent testing the functionality of the product, not reworking bugs	Process	(Barnett, et al., 2002)			
Function point/staff month, function point/team month (and the less desirable computer language dependent equivalents for lines of code - KLOC)	Process	(Barnett, et al., 2002)			
Cycle time	Process	(Barnett, et al., 2002)	e.g. calculating the average number of approvals required for each enhancement request could be useful if customers perceive that the team is not responsive to new feature requests		
Actual vs. Estimate (cost, days)	Process	(Barnett, et al., 2002)			

Percentage of process-level deliverables within plus-or-minus 10 percent of estimated completion time or business deadline	Process	(Barnett, et al., 2002)	In defining the timetable for completing a project, it is important to estimate the amount of time needed to complete each stage of development. Measuring frequency with which a development organization meets (or beats) these target dates might illuminate the parts of the development process that need to be improved.		
Days saved due to code reuse	Process	(Barnett, et al., 2002)			
Time to market for a new application [...]	Process	(Barnett, et al., 2002)			
Customer reported defects	Process	(Barnett, et al., 2002)			
Creative Potential	Input	(DiLiello, et al., 2008)	Several survey items are used to measure creative potential (e.g. "I have a knack for further developing the ideas of others", ...)		
Practiced Creativity	Input	(DiLiello, et al., 2008)	Several survey items are used to measure creative potential (e.g. "My creative abilities are used to my full potential at work", ...)		
Perceived Organizational Support	Input	(DiLiello, et al., 2008)	Several survey items are used to measure creative potential (e.g. "Rewards are given for innovative and creative ideas", "Ideas are judged fairly in this organization", ...)		
Frequency and diffusion of learning behaviors	Process	(Gieskes, et al., 2004)			

Percentage of project aligned with strategy	Process	(Symons, 2004)			Development Scorecard / IT Value Perspective
Actual versus planned budget	Process	(Symons, 2004)			Development Scorecard / IT Value Perspective
Total project ROI	Output	(Symons, 2004)			Development Scorecard / IT Value Perspective
User satisfaction	Output	(Symons, 2004)			Development Scorecard / User Perspective
Percentage of projects on schedule	Process	(Symons, 2004)			Development Scorecard / Process excellence perspective
Percentage of projects on or under budget	Process	(Symons, 2004)			Development Scorecard / Process excellence perspective
Actual versus planned defects	Process	(Symons, 2004)			Development Scorecard / Process excellence perspective
Percentage of staff that meets competencies	Input	(Symons, 2004)			Development Scorecard / Future orientation perspective
Code reuse versus code plan	Process	(Symons, 2004)			Development Scorecard / Future orientation perspective
Number of procedure parameters	Process	(Sommerville, 2001)	influences e.g. maintainability, portability		
Cyclomatic complexity	Process	(Sommerville, 2001)	This is a measure of the control complexity of a program. This control complexity may be related to program understandability [influences e.g. maintainability, reliability].		
Program size in lines of code	Process	(Sommerville, 2001)	influences e.g. maintainability, reliability, portability		
Number of error messages	Process	(Sommerville, 2001)	influences e.g. reliability, usability		

Length of user manual	Process	(Sommerville, 2001)	influences e.g. maintainability, usability		
Fan-in/Fan-out	Process	(Sommerville, 2001)	Fan-in is a measure of the number of functions that call some other function (say X). Fan-out is the number of functions which are called by function X. A high value for fan-in means that X is tightly coupled to the rest of the design and changes to X will have extensive knock-on effects. A high value for fan-out suggests that the overall complexity of X may be high because of the complexity of the control logic needed to coordinate the called components.		
Length of code	Process	(Sommerville, 2001)	This is a measure of the size of a program. Generally, the larger the size of the code of a program component, the more complex and error-prone that component is likely to be.		
Length of identifiers	Process	(Sommerville, 2001)	This is a measure of the average length of distinct identifiers in a program. The longer the identifiers, the more likely they are to be meaningful and hence the more understandable the program.		
Depth of conditional nesting	Process	(Sommerville, 2001)	This is a measure of the depth of nesting of if-statements in a program. Deeply nested if-statements are hard to understand and are potentially error-prone.		

Fog index	Process	(Sommerville, 2001)	This is a measure of average length of words and sentences in documents. The higher the value for the Fog index, the more difficult the document may be to understand.		
Depth of inheritance tree	Process	(Sommerville, 2001)	This represents the number of discrete levels in the inheritance tree where subclasses inherit attributes and operations (methods) from superclasses. The deeper the inheritance tree, the more complex the design as, potentially, many different object classes have to be understood to understand the object classes at the leaves of the tree.		
Method fan-in/fan-out	Process	(Sommerville, 2001)	This is directly related to fan-in and fan-out as described above adn means essentially the same thing. However, it may be appropriate to make a distinction between calls from other methods within the object and calls from external methods.		

Weighted methods per class	Process	(Sommerville, 2001)	This is the number of methods included in a class weighted by the complexity of each method. Therefore, a simple method may have a complexity of 1 and a large complex method a much higher value. The larger the value for this metric, the more complex the object class. Complex objects are more likely to be more difficult to understand. They may not be logically cohesive so cannot be reused effectively as superclasses in an inheritance tree.		
Number of overriding operations	Process	(Sommerville, 2001)	These are number of operations in a superclass which are overridden in a subclass. A high value for this metric indicates that the superclass used may not be an appropriate parent for the subclass.		
Focus factor	Process	(van Puffelens, 2007)	Percentage of time that is used to work on the planned/estimated tasks/times (compensates for meetings, discussions, coaching, ... - which were not included in estimations)		
Velocity	Process	(Barnett, 2005)	number of units completed in an iteration	Productivity	
Average productivity	Process	(Barnett, 2005)	velocity / number of team members	Productivity	
Number of features delivered versus planned	Process	(Barnett, 2005)		Productivity	

Percentage of features delivered versus planned	Process	(Barnett, 2005)		Productivity	
Number of tests/test points completed	Process	(Barnett, 2005)		Productivity	
Number of defects found in production (by priority, severity, source)	Output	(Barnett, 2005)		Quality	
Rate of discovery	Process	(Barnett, 2005)		Quality	
Rate of discovery versus rate of resolution	Process	(Barnett, 2005)		Quality	
Broad estimation (days, dollars); actual versus estimates	Process	(Barnett, 2005)		Project/cost management	
Functionality used versus built	Process	(Barnett, 2005)		Project/cost management	
Utilization/billable ratio	Process	(Symons, 2004)			Learning and Growth (Future Orientation)
Percentage of work done by contractor	Input	(Symons, 2004)			Learning and Growth (Future Orientation)
Percentage of staff with completed professional development plan	Input	(Symons, 2004)			Learning and Growth (Future Orientation)

Retention/ turnover by performance level	Input	(Symons, 2004)			Learning and Growth (Future Orientation)
Score on employee satisfaction survey	Input	(Symons, 2004)			Learning and Growth (Future Orientation)
Number of documented best practices	Process	Symons, 2004)			Learning and Growth (Future Orientation)