The many applications of patent analysis

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Journal of Information Science 2002 28: 187
DOI: 10.1177/016555150202800302

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Received 20 October 2001
Revised 4 February 2002

Abstract.

The use of patent analysis in many different contexts is discussed. Applications discussed range from intellectual property management, to merger and acquisition targeting and due diligence, to stock market valuation. The authors draw on 38 years of combined patent-related experience to discuss a number of techniques and metrics that have been found to work well in specific situations.

1. Introduction

Patent analysis has applications to many different tactical and strategic company assessments. In this article, applications that range from those dealing directly with patents, such as intellectual property management, to those farther removed, such as company valuation and competitive intelligence, are discussed.

This article is very application oriented and discusses numerous business situations where patent analysis is appropriate. Warnings are given where appropriate, but since this is primarily an application paper the theory is not extensively discussed nor the pros and cons of every technique.

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While the paper is not primarily about citation analysis, since citation analysis is a key technique used in many applications, a short description and history of validation studies is given in the Appendix. For readers who wish to learn in more detail about patent metrics in general and patent citation analysis specifically, there are numerous review articles that discuss various techniques critically [1–3].

2. Intellectual property management

The distribution of value across a company's patent portfolio is highly skewed, with a small number of valuable, high-impact patents and large numbers of patents of marginal importance. Patent analysis can help professionals in intellectual property (IP) focus their time and efforts on those patents and activities that add the most value to a company.

2.1. Patent portfolio inventory and organization

One of the first steps a company must take to begin managing its patent IP is to conduct an inventory and organize its patent portfolio. Many companies, especially those with very large portfolios, may not know how many patents they own, what technologies they are in, what countries they have protection in, how long the remaining patent terms are, or even whether a given patent has lapsed or not.

Before the advent of modern information technology, inventorying and assessing a company's patent portfolio was typically a long and laborious effort, extremely intensive in high-priced professional time. Today, with electronic databases, a company can conduct patent searches on its internal database of patents or on public databases. Analytical software can classify and screen patents, allowing professionals to focus their evaluation on those patents most likely to be strategically important. Software products and special services are now available for assisting in the analysis of patent portfolios. Some of these are summarized in Table 1.

Patent inventory. In the inventory step, a company obtains a complete list of its patents. It is important for a company to maintain a complete and up-to-date database of its patents. If it has such a database, the

Table 1
Summary of selected patent analysis software and services

Company: product	Description	Features	Delivery mechanism
Search Technology: VantagePoint	Text and data mining tool	Lists of authors, affiliations, or countries; cross-tab tables of two data fields against one another (e.g. inventors by number of patents per year); cluster maps	Software installed at corporate location www.thevantagepoint.com
Wisdomain: PatentLab-II	Patent analysis tool for use with data from Delphion search site	Rows can be: assignee, patent class, priority country, inventor, priority year/patent year; Columns can be: assignee, patent class, priority year	User downloads search result from web to desktop and conducts analysis there www.wisdomain.com www.delphion.com
MicroPatent: PatGraph	Patent analysis tool that works with data from MicroPatent search site	Patent counts for top 10 assignees and top 10 IPCs; patent counts for top 10 assignees by issue date; general patenting trends over time	Accessed via the Web www.micropatent.com
Aurigin: Aureka (formerly IPAM)	Knowledge management system with patent analysis capabilities	Inventor trends, assignee trends, patenting 'velocity', life-cycle, IPC trends; thematic maps; citation trees	Intranet based; client-server sits behind corporate firewall. Companies pay to establish system and then pay on a subscription basis for updates to patent data. Also available on the Internet. www.aurigin.com
Mogee Research and Analysis Associates: Patent Citation Reports	Patent citation reports based on US patents, covers any number of patents	Lists of citing and cited patents; highly cited patents, assignees, and inventors; citation time lags, self- and other-citations; citation matrix, citation map	Order reports on the Internet: www.mogee.com
CHI Research: Tech-Line	Patent indicator database of 1500 companies	Trends by company or technology category – number of patents, cycle time, current impact index, technological strength, science linkage, science strength, etc.	Individual reports available at www.economy.com or contact CHI at www.chiresearch.com
CHI Research: Custom Databases and Reports	Custom patent databases and standard reports.	MS Access databases of well-defined patent extractions with built-in searching, clustering, and patent metrics, plus standard and user defined reports of activity trends, highly cited patents, top inventors and assignees and other patent metrics	Available on custom basis. Contact CHI at www.chiresearch.com or info@chiresearch.com

company may use it for its inventory. Otherwise it must search public patent databases to find out what the public record says. This is not as easy as it sounds. The company may have sold or acquired business units over the years or merged with another company. The disposition of specific patents in these cases is not always easy to trace. The original patent owner may have reassigned a patent. Sometimes the parties report reassignments to the patent office, which records them in a public database, but often they do not.

If a company patents only in the US, it may limit its search to US patent databases. If the company patents in other countries, however, it must search in databases that cover international patenting. These include the Derwent World Patents Index (WPI), INPADOC, European Patent Office databases, or PLUSPAT. If wanted, the inventory can include patents belonging to subsidiaries or other related firms, and patents obtained through mergers, acquisitions or purchase of the technology. A search of reassignments may also turn up patents that the company has reassigned to other companies. Certain patent databases can identify patents that have expired or lapsed and are no longer valid.

Grouping patents. To understand the strengths and weaknesses of a company's patent portfolio, organizing the portfolio by technology, product or business unit is very useful. An initial sorting by US patent classification (USPC) or the International Patent Classification (IPC) is simple and can be informative.

As an example, Fig. 1 shows the top 15 IPC categories for which GE had US patents granted in the year 2000. It can be seen that, although GE has revenues from a variety of sources, including financial services, broadcasting, aircraft engines, appliances, etc., much of its patented technology is related to medical equipment and engines/turbines.

Alternatively, one can use a co-occurrence technique such as co-citation, co-word, or co-classification analysis to cluster the patents in the company's portfolio. These techniques determine similarities among patents based on common patterns of citation, text or classification. They group similar patents together, revealing the internal structure of the portfolio. For example, a co-citation linkage exists between two patents if they are both cited in a single later patent. A large number of co-citation links between two patents is evidence that they are closely related to one another. Co-cited patents often link up to form clusters of related patents.

Table 2 shows the results of co-citation clustering of Eli Lilly & Co.'s patent portfolio [4]. Lilly received about 2800 US patents from 1975 through 1998. Of these, 750 patents formed 132 clusters, which in turn formed 13 groups. These groups represent significant areas of strength in Lilly's portfolio.

2.2. Technology transfer and licensing

Technology transfer and licensing is another important area of intellectual property management where patent analysis can be helpful. For example, patent analysis can help identify specific patents for out-licensing, and the companies most likely to be interested in in-licensing those patents.

Patent citation analysis can help a company identify patents that may not be of current value because they are not related to its core technology, but may be of interest to other companies. For example, Fig. 2 is a matrix showing the patents belonging to the company Xaar and all the patents that cite Xaar's patents. Figure 2 lists Xaar's patents across the top and it lists the citing patents and their assignees on the left side. Several companies, besides Xaar itself, have cited Xaar's patents. Patents cited by Xaar itself represent stepping stones of technology on which Xaar continues to build. These are clearly of continuing value to Xaar and should not be licensed out without considering Xaar's interests. Note, however, that Xaar has not cited five of its patents: 4992808, 5028936, 5189437, 4973981 and 5003679. These patents may be outside Xaar's strategic interests or perhaps they did not 'pan out' for Xaar for some reason. Xaar might investigate them further to ensure that they are not of potential value to the company and thus are candidates for out-licensing.

Figure 2 also shows that Brother has heavily cited four of the five patents not cited by Xaar. Brother has cited one of these patents seven times and three patents five times. This suggests that these patents are of high interest to Brother. It is possible that Brother is working in a closely related area or even building on the work of Xaar (it is even possible that some of Xaar's patents are being infringed and a license agreement is called for). Hewlett Packard has cited the fifth patent not cited by Xaar four times, indicating that the patent has potential value to Hewlett Packard. Xaar can study the specific citing patents to understand the relationships with their own. This can provide information helpful in negotiating a license and its terms.

Citation analysis can help ensure that a company does not mistakenly license-out patents that are necessary to work with the patents to which it retains rights. Conversely, a company that is licensing-in can also use the technique to ensure that it gets rights to all the

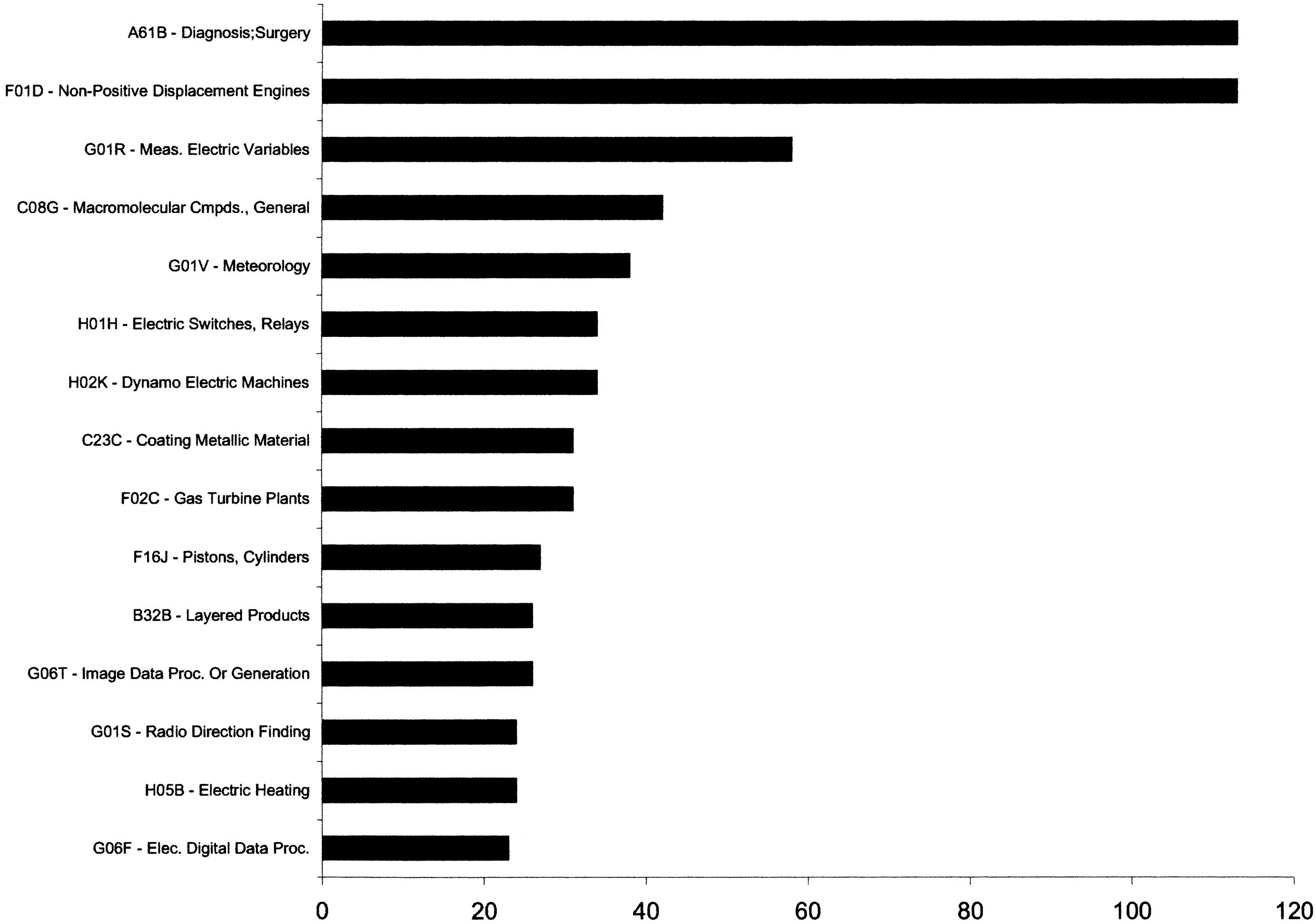

Fig. 1. Top 15 IPC categories of GE patenting (number of year 2000 US patents).

patents that are necessary to practice the technology. Figure 3 illustrates this with a co-citation cluster of IBM patents related to fabricating electronic packages using film chip carriers [5]. The many linkages between patents in the central ring show that they all inter-relate highly with each other. Licensing-out a central patent in the cluster might make it difficult for IBM to continue to practise this technology. Conversely, the company that is licensing-in may wish to license the entire cluster of patents to be sure it has all the rights it needs to practise the technology.

2.3. Cross-licensing support

Cross-licensing is a special case of licensing in which companies license their entire portfolios to each other. It is common in the electronics and computer industries where it gives companies freedom to operate. Here patent analysis has a role in comparing the patent portfolios of companies. It helps the analyst to see where the portfolios overlap, to identify the key patents, to make judgments about which company has the stronger position, and to decide who should pay whom and how much.

Patent citation analysis can inform cross-licensing negotiations in much the same way it does patent licensing. Let's say that Company A is negotiating with Company B and that their portfolios are roughly the same size. If Company A can argue strongly that its portfolio is more valuable than that of Company B, then it may require Company B to pay a fee. The fee may be roughly equal to the difference in the value of the two portfolios. The number of citations received by Company A's patents compared with the number received by Company B's patents gives an indicator of relative value of the portfolios. The analyst may also

Table 2
Co-citation groups in Eli-Lilly & Co.'s patent portfolio (1975–1998)

Group no.	Category
G1	Phenylalkylamines
G2	Drug delivery
G3	Pyradine derivatives
G4	Antibiotics, including genetic engineering approaches
G5	Compounds with activity against the central nervous system and cardiovascular system
G6	Hydroisoquinolines, piperidines, aromatase inhibitors
G7	Isothioazolecarboxylic acids and pyrazole carboxylic acids
G8	Dibenzopyranes, nitroglycerin tablets, dibenzopyranone
G9	Cephalosporins
G10	Various antibiotics and genetic engineering
G11	Hormone-related compounds for reproductive, osteoporosis, diabetic and cancer treatment
G12	Leukotriene antagonists
G13	Antiarrhythmic agents, phenethanolamines, aryloxyphenylpropylamines

look at how often Company B cites Company A's patents and vice versa, to get an indicator of whether A's patents are more valuable to B or B's patents are more valuable to A. Highly cited patents probably have disproportionate value to the company or industry. The licensing professional can factor all this information into the negotiation.

Figure 4 shows the 'licensing potential score' for IBM and Toshiba patents in US Patent Class 250 'Radiant Energy'. The licensing potential score is calculated based on the number of citations a patent receives from 'other' companies (not the company that owns it), corrected for the age of the cited patent. Because citations accumulate over time, older patents may have more citations than younger patents simply because they are older, not because they are more important. Figure 4 shows that Toshiba's patents in this field are of average value, while those of IBM are much more valuable than average. In a cross-licensing agreement between these two companies, Toshiba would presumably pay a fee to IBM.

CITING COMPANY	CITING PATENT	4887100	5016028	4942409	5010356	4929256	4940996	4992808	5028936	5189437	4973981	5003679	5010125	5028812	TOTAL
AT&T	4973981	X	.	.	.	.	.	.	.	.	.	.	.	.	1
	5016028	X	.	.	.	.	.	.	.	.	.	.	.	.	1
Brother	5086308	X	.	.	.	.	.	.	.	.	.	.	.	.	1
	5245244	X	X	X	.	X	X	X	X	.	X	X	.	.	9
	5302976	X	X	X	.	X	X	X	X	.	X	X	.	.	9
	5363133	X	X	X	.	X	X	X	X	.	X	X	.	.	9
	5396272	X	.	X	.	.	X	.	.	X	X	.	.	.	5
	5410341	X	X	X	.	.	X	.	.	.	X	.	.	.	5
	5421071	X	X	X	.	X	X	X	X	.	X	X	.	.	9
	5434608	X	.	X	.	X	X	X	X	.	X	X	.	.	8
Canon	5184148	.	.	.	.	.	.	.	.	.	.	.	X	.	1
Citizen Watch	5359354	X	X	.	.	.	.	.	.	.	.	.	.	.	2
Compaq	5227813	X	.	.	.	.	.	.	.	.	.	.	.	.	1
	5235352	X	X	.	.	.	.	.	.	.	.	.	.	.	2
	5373314	X	X	.	.	.	.	.	.	.	.	.	.	.	2
	5400064	X	X	.	.	.	.	.	.	.	.	.	.	.	2
	5402162	X	X	.	.	.	.	.	.	X	.	.	.	.	3
	5406319	X	X	.	.	.	.	.	.	.	.	.	.	.	2
	5426455	X	X	.	.	.	.	.	.	.	.	.	.	.	2
	5430470	X	.	.	.	.	.	.	.	.	.	.	.	.	1
	5433809	X	X	.	.	.	.	.	.	.	.	.	.	.	2
	5436648	X	X	.	.	.	.	.	X	.	.	.	.	.	3
	5440332	X	.	.	.	.	.	.	.	X	.	.	.	.	2
	5444467	X	X	.	.	.	.	.	X	.	.	.	.	.	3
HP	5291226	.	.	.	.	.	.	.	.	X	.	.	.	.	1
	5300959	.	.	.	.	.	.	.	.	X	.	.	.	.	1
	5371527	X	X	.	.	.	.	X	.	.	.	.	.	.	3
	5408738	.	.	.	.	.	.	.	.	X	.	.	.	.	1
	5442384	.	.	.	.	.	.	.	.	X	.	.	.	.	1
SONY	5371529	.	.	.	.	.	.	X	.	.	.	.	.	.	1
XAAR	5097637	.	.	.	.	X	.	.	.	.	.	.	.	.	1
	5112398	.	.	.	.	.	.	.	.	.	.	.	X	.	1
	5121134	.	.	X	X	.	X	.	.	.	.	.	.	.	3
	5194475	.	.	.	.	.	.	.	.	.	.	.	X	.	1
	5361084	X	X	.	.	.	.	.	.	.	.	.	.	.	2
	5369420	X	X	.	.	.	.	.	.	.	.	.	.	X	3
	5438350	X	.	.	.	.	.	.	.	.	.	.	.	X	2
	Total	27	18	8	1	6	8	7	7	7	7	5	3	2	106

Fig. 2. Citation matrix of US patents and their assignees that have cited Xaar patents sorted by citing company.

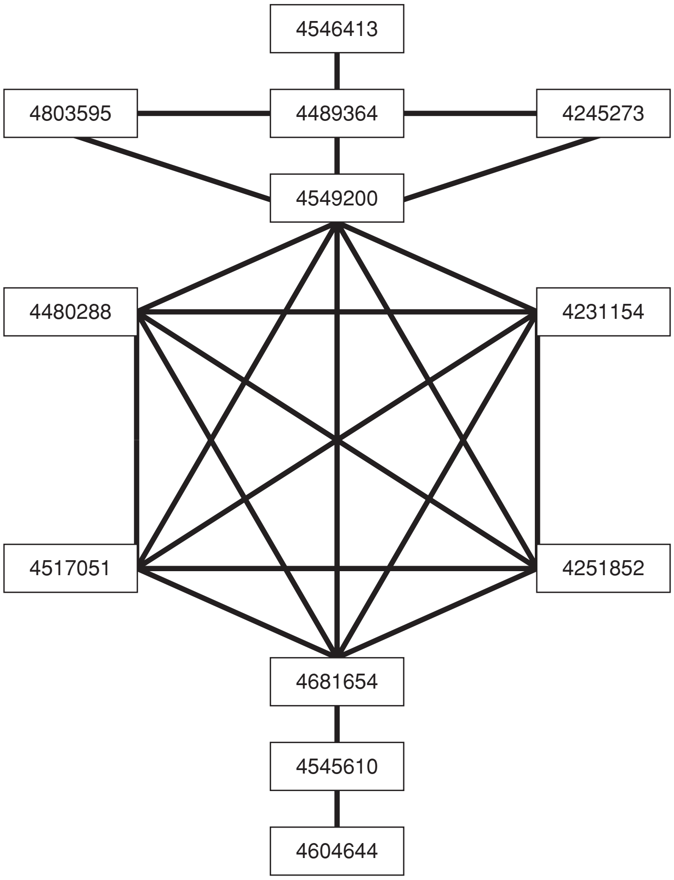

Fig. 3. Related patents identified via co-citation clustering.

2.4. Donation targeting

Companies often have patents for which they have no commercial use. One method of extracting value from these is to donate them to universities or other public research organizations and take a tax deduction. A decision to donate a patent depends on the assessment that the patent is no longer of value to the company that owns it. The rate of 'company self-citation', i.e. citations from the company's own later patents – is one indication of a patent's value to the company. If it has not been self-cited, or at least not for a long time, the patent may no longer be important to the company's intellectual property (IP) domain. The ability to take a tax deduction depends on being able to argue that the patent has value to other parties. A high or growing number of 'other' citations can support such an argument.

Average Licensing Potential Score

Toshiba	IBM	Class Avg.
0.65	1.04	0.63

Potential = age adjusted frequency of citations from other companies

Fig. 4. Comparing company portfolios US Patent Class 250, 'Radiant Energy'.

2.5. Decisions on whether to pay maintenance fees rest on similar considerations

Companies should also evaluate patents to decide if it is still worth paying a maintenance fee to keep them in force. Is this patent still important to our IP domain? Does our current research and development (R&D) programme continue to build upon it? If a patent has not received many 'self' or 'other' citations, that suggests that the patent has little value to anybody. This information would argue for letting the patent lapse, other things being equal. If a patent has not received many 'self' citations, but other companies have cited it heavily, that suggests that the originating company might seek to license the patent to another company, rather than letting it lapse.

3. R&D management/technology assessment

Besides being of interest in their own right, patents can also serve as 'indicators', or indirect measures, of company commitment to R&D and technology. For example, if one company has more patents than another, this suggests that the first firm has a stronger commitment to technology R&D. Other things being equal, one would expect the first firm to be better able to develop new products, processes, or services based on this technology.

3.1. Core technological competence

A company's core technological competence is often revealed by identifying technologies in which it both patents intensively and has highly cited patents [6]. Using this basic technique, one may compare companies with respect to various categories into which their patents fall. For example, if one is comparing automobile companies, one might calculate each company's technological profile in terms of the number or proportion of its patents that fall into various patent categories such as engines, transmissions, suspension etc. This is a good way to measure patent activity, but in order to

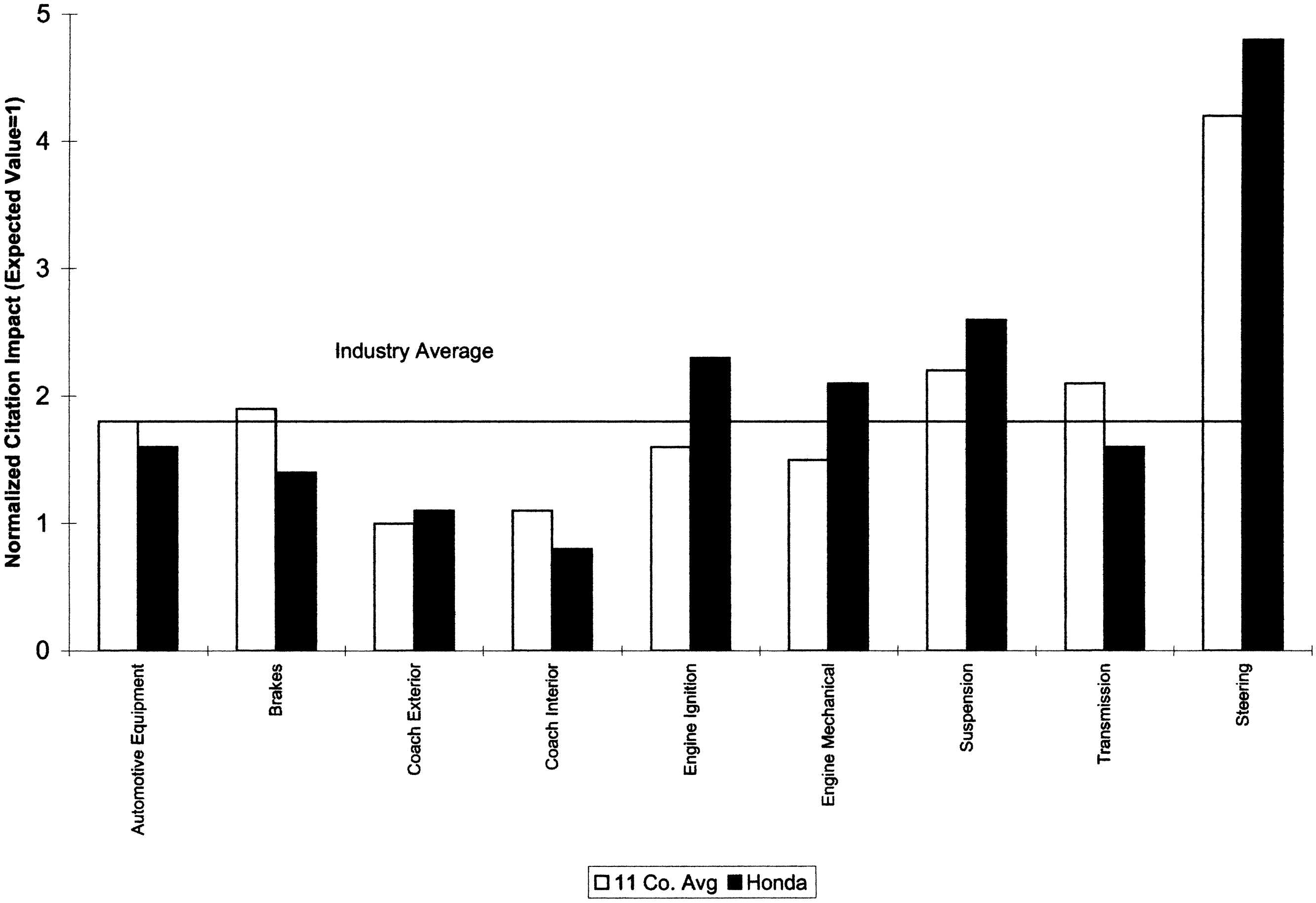

Fig. 5. Honda vs industry – citation impact 1986–1990.

measure technological competence, one needs to weight the categories by citation impact or some other measure.

For example in Fig. 5 (modified from Narin [6]) we see that Honda's core competencies are in engines, suspension, and steering, but it is weaker in coach interior, exterior or transmissions.

Co-citation analysis, mentioned earlier, or other co-occurrence techniques may also be used to identify areas of core competence. Often, when we cluster a company's patents, some clusters are especially strongly inter-related, both internally and with other clusters. These represent areas of technology that are particularly important to the firm, areas where it has conducted a substantial amount of R&D and has built up an accumulation of knowledge and capability. Other clusters may have weaker links between member patents and may not relate closely to other clusters in the portfolio. These represent areas of technology where the company has conducted R&D, but that are less focused and less central to the company's core interests.

Figure 6 shows results of clustering Allergan's patent portfolio. It shows four areas of technological activity: compounds with retinoid-like activity, optical hypotensives, intra-ocular implants and disinfecting contact lenses. The size of an oval represents the number of patents in a cluster and the distance between ovals is proportional with the strength of the co-citation link. The shade of an oval indicates how heavily Allergan has cited the patents in that cluster within the last few years. This is an indicator of how heavily Allergan's R&D continues to build on this area. Allergan has cited black ovals heavily in recent years, they have not cited white ovals much in recent years, and grey ovals fall between. It appears that retinoid-like compounds are an area of intense, highly focused R&D that Allergan continues to build upon. On the other hand, disinfecting contact lenses, a traditional business

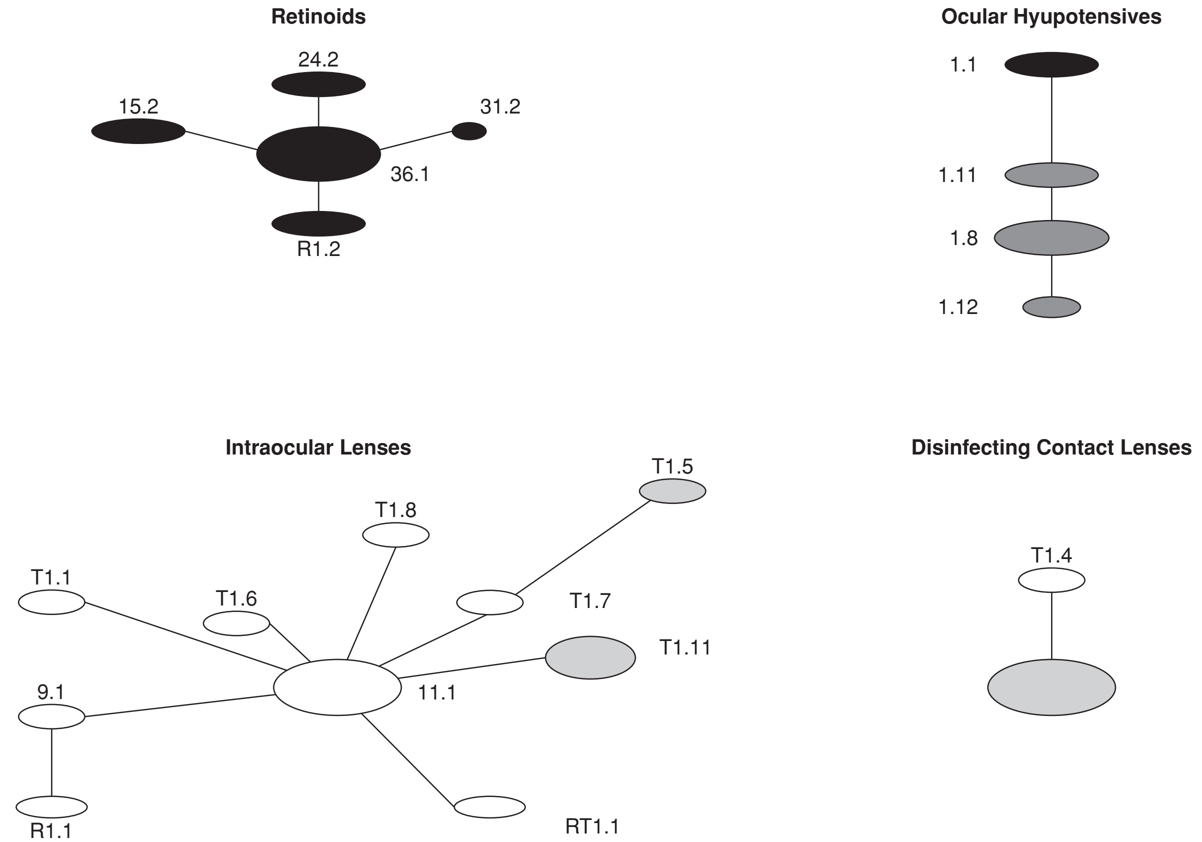

Fig. 6. Clusters of competencies represented in Allergan's patent portfolio.

for Allergan, may be an area that it no longer regards as an area of core research interest. It shows a low level of activity, not much focus, and may not be of continuing research interest to Allergan. The alphanumeric code next to each oval is simply an identifying label.

3.2. Technology assessment

Using the same methods, an analyst may assess a technology category or categories and determine which companies have the strongest and weakest technology therein. Making projections about where a technology is headed is also possible.

Figure 7, from a study of global patenting (covering more than 40 countries) in papermaking machinery, shows the relative positions of the top five firms on five patent indicators:

Number of patent families. A patent family is the collection of patents in different countries that protect the same invention. The number of patent families assigned to a company is an indicator of its level of R&D or technological activity.

Number of international patent families. An international patent family is a family with patents in more than one country. The number of international patent families assigned to a company is an indicator of the level of R&D or technological activity intended for international exploitation.

Number of foreign patents. A foreign patent is a patent in a country other than the home country of the company. The number of foreign patents assigned to a company is an indicator of its intent to exploit technology broadly internationally.

Mean international family size. The size of a family is the number of countries represented. The mean (average) size of a company's international patent families is another indicator of its intent to exploit technology broadly internationally.

Number of citations received. The number of citations received by a company's patent families is an indicator of the technological significance of its inventions.

Each indicator is represented on one leg of the 'spider'. Each indicator is scaled from zero at the centre to 1 at the end, where the highest score is set at 1.

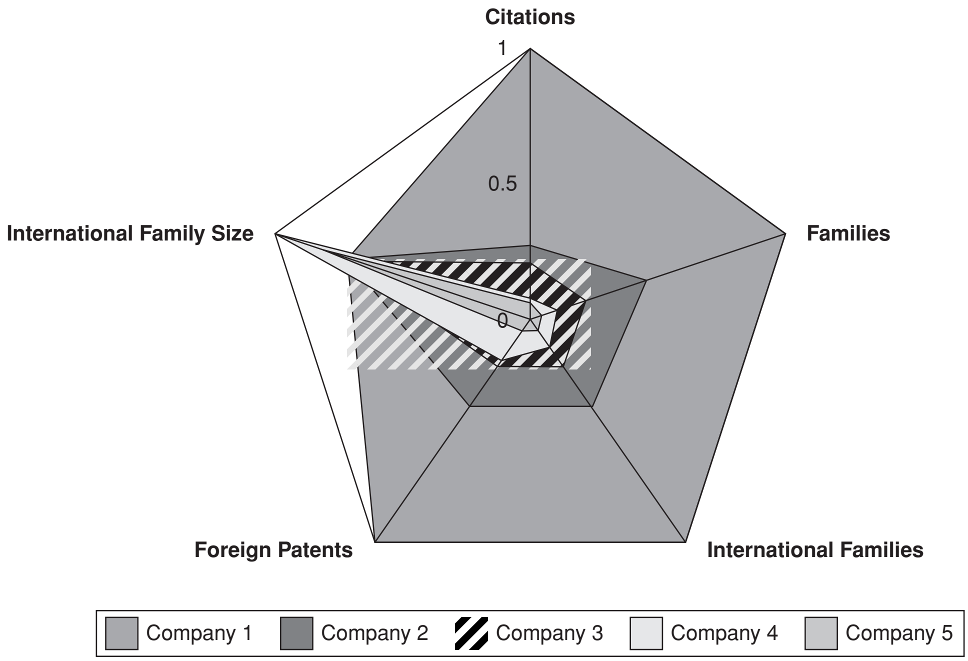

Fig. 7. Relative position of five firms on five patent indicators.

Figure 7 indicates that Company 1 is the leader by far on four of the five indicators. Only on one indicator – mean international family size – does another company lead: Company 4. We compared these positions for two periods and found little change over time. This suggests that Company 1 has dominated this field of technology and continues to do so.

The study further broke the patents into six technology groups:

Hard rollers
Soft rollers
Bearings
Controls
Doctors and winders
Feeding and guiding paper

Figure 8 shows the distribution of activity across these groups in two periods. Based on changes in patenting, it appears that R&D in hard rollers and controls increased. Activity in bearings decreased and activity in the other areas remained stable. By extrapolation, these trends may suggest the directions in which the technology will be going in the near-term future. A company in this industry could use this information to decide which areas of R&D it should strengthen, or which it could drop. It could also learn of new products and new processes potentially coming from competitors.

4. Human resources

Patent documents provide a vast resource for identifying key personnel within a company, areas where a company is vulnerable should an inventor leave, and key experts that may be willing to join a company. Part of the power of these techniques is related to the skewness of inventor productivity – in any laboratory or company there will be a small number of highly prolific inventors, and large numbers who produce only one or two patents.

Our consulting work has repeatedly shown that a few key inventors drive technological development within a company. Narin and Breitzman [7] quantified this phenomenon, showing that Lotka's law [8] for scientific output also holds for patents. If a company has 100 inventors with one patent in a period, it will have only $100/2^2$ or 25 inventors with two patents, $100/3^2$ or 11 inventors with three patents, and so on. Typically, only one or two inventors will have 10 or more patents in the period. Figure 9 illustrates this for inventors at Xerox. Note that each stick within the diagram represents an inventor, and the height of the stick is the number of patents he or she has (thus 119 inventors have one patent, 16 have three, and only one has more than 18 patents).

One human resource implication of this phenomenon is that it is vitally important for a company to keep

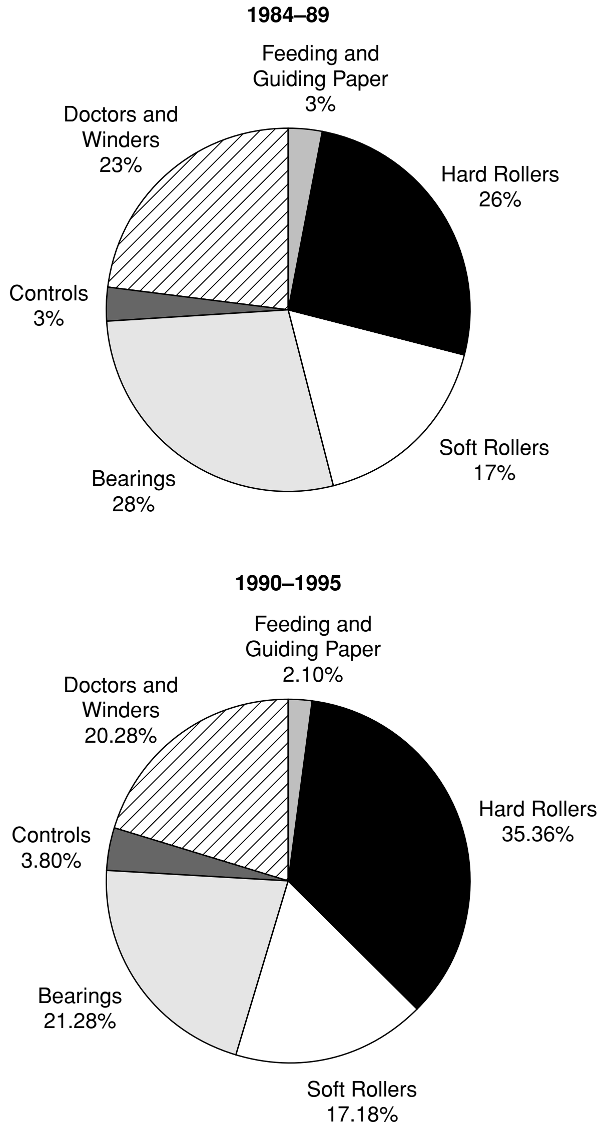

Fig. 8. Change in direction of a paper-making machinery technology.

its key inventors happy. However, the implications go far beyond this. Companies that do not have a key scientist in an area of technology are often mediocre compared with their competitors. It is therefore crucial for a company to know where its key experts are relative to its product line. It is then possible to assess which areas are dependent on a few key individuals, which areas have no key individuals, and in which areas the company needs to take steps before key people retire.

Figure 10, called a co-inventor brainmap is from a project related to anti-thrombotics. This map represents the patents of a set of Bristol–Meyers-Squibb inventors working in a niche area related to anti-thrombotics. Note that each square or circle mark identifies a patent–inventor (square marks the inventor in each group with the most overall patents) combination. Vertical lines connect inventors who work together. As indicated by the time line, this snapshot was taken in the middle of 1994.

What can one learn about human resources from a brainmap? First, notice that, although 21 individuals work in the area, three individuals – Masami Nakane, Steven Hall and Jagabandhu Das – drive the development. Moreover we see that Nakane is no longer active after 1989. This raises some questions: should more have been done before Nakane retired to keep the stream of inventions in this area alive? With the proper support could Joyce Reid have continued Nakane's work? Next, notice Steven Hall who suddenly has a cluster of collaborators in 1989. Was this done to ensure his stream of work continues after he retires? Brainmaps are quite useful for analysing these types of questions. They can also help find areas of technology where there are no dominant scientists and areas where expertise has declined over time.

Being an expert means more than being prolific. Another measure of an expert or 'star' is the significance or influence of his or her work. The analyst can measure these qualitative aspects of an inventor's output by weighting his/her patents by citation impact, by science linkage (whether they cite to research papers, an indicator of leading edge activity), or by other patent indicators. These weighting techniques can identify star inventors within a company, or star capabilities outside a company. Identifying key inventors in other firms is a useful technique for headhunting. It may also be crucially important in merger/acquisition targeting, as discussed below.

5. Mergers and acquisition

5.1. Merger/acquisition targeting

Patent analysis can be used to identify the best merger/acquisition target from a technological perspective – that is, the target with the best technology at the best price. Quite often a company that wishes to acquire a specific capability has no idea where to begin looking. One way to overcome this is to identify all companies with patents in the area of interest.

For example, say a security firm wishes to acquire a company that specializes in biometrics. Figure 11 shows a patent search strategy (also called a filter) for

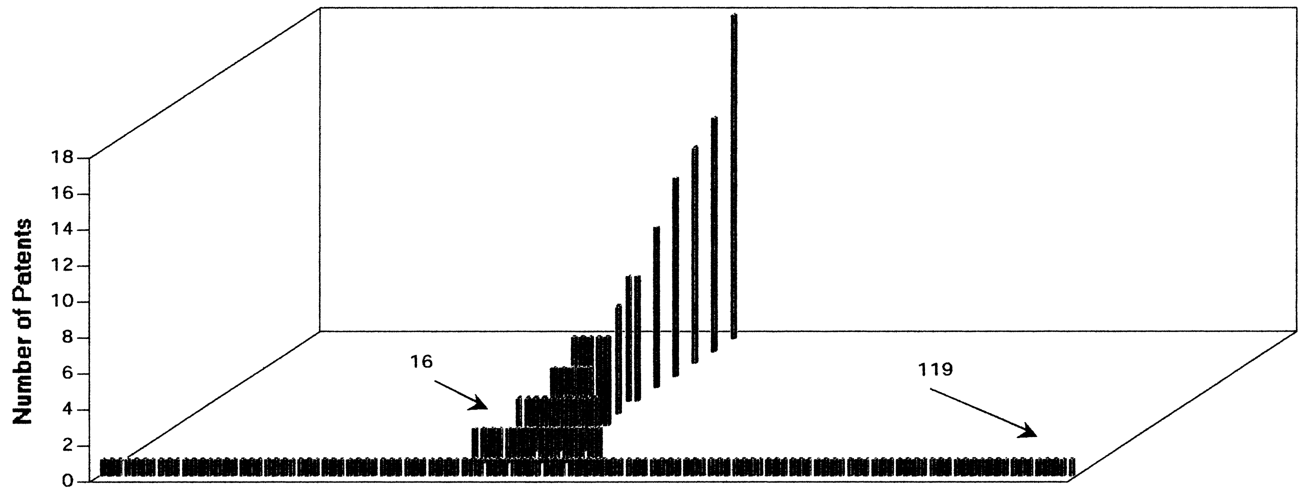

Fig. 9. A few key inventors drive an entire laboratory. Xerox semiconductor inventors 1981–1987. Each stick represents one Xerox inventor: the height is the number of his/her patents in the eight-year period.

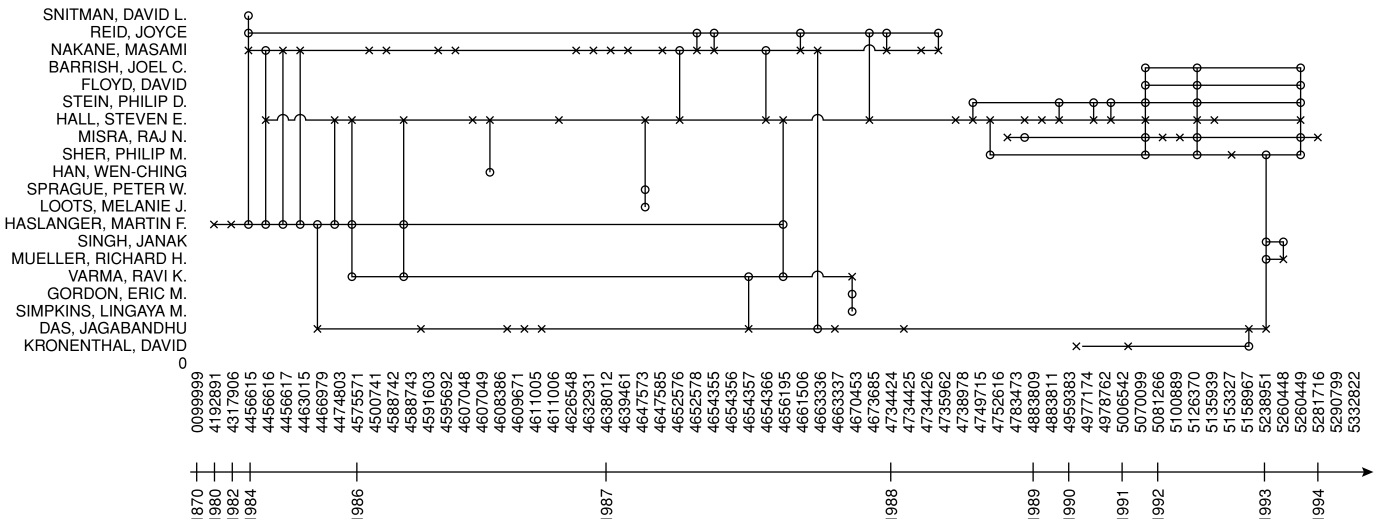

Fig. 10. Brainmap of Bristol–Meyers Squibb in Antithrombotics.

identifying patents related to biometrics. This search uses a combination of patent classifications and text terms to identify all patents related to biometrics. Once all of the patents are identified, one can list the assignees who own them. This is a list of the firms that have patented technology related to biometrics.

Once the potential targets are identified, one can apply standard patent analysis to narrow down the choices. As an example, Fig. 12 shows the five most active companies in ultrasound technology. Acuson is one of the most active companies. Further, its high citation impact and science linkage indicate its ultrasound technology is quite strong.

Another indicator of Acuson's technology strength is shown in Fig. 13. This figure takes the peer companies and shows which company each cites most and second-most. Acuson has five arrows pointing to it, indicating its ultrasound patents are cited most or second-most by five of the six peer companies. Note that the numbers next to each arrow indicate the total citations from the first company to the second company's ultrasound patents. Thus, GE cites Siemen's ultrasound patents 37 times.

Additional patent analyses can be done on the target companies to determine which of the companies is the best acquisition target, from a technology perspective.

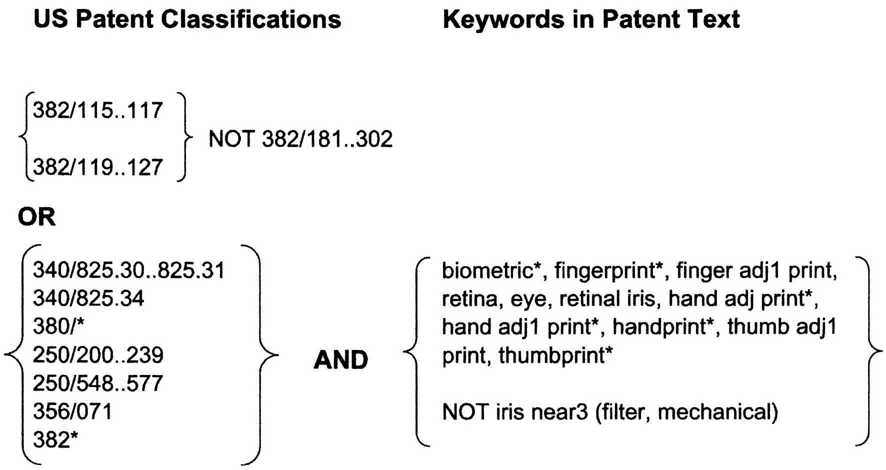

Fig. 11. Filter strategy for identifying biometric patents.

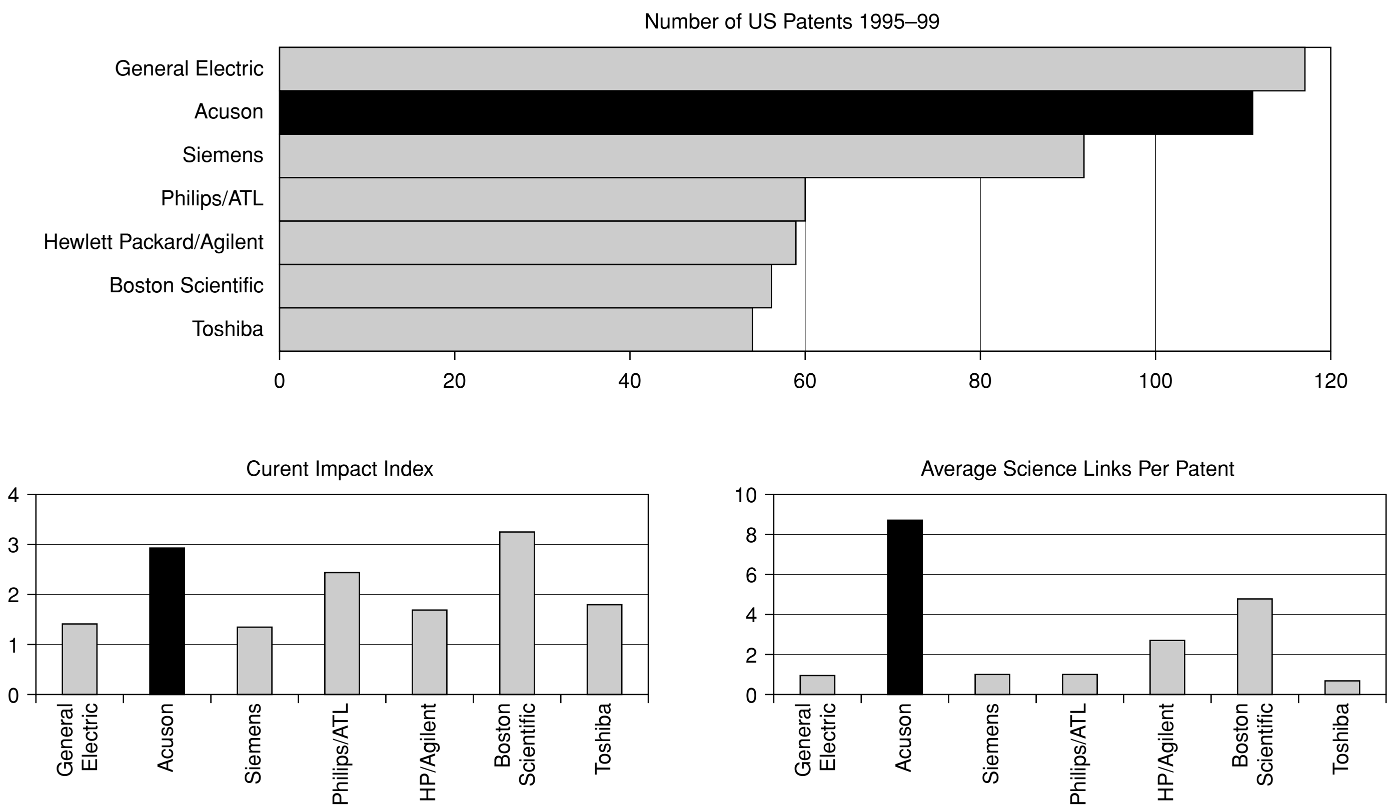

Fig. 12. In the last five years, Acuson is one of the most prolific patenters, its patents are highly influential, and have the closest links to scientific research.

These include analyses discussed above in Section 3, and those discussed below in Sections 6 and 7 as well as techniques that can be found in Breitzman *et al.*, among others [9, 10].

5.2. Due diligence

Once a Mergers and Aquisitions analyst identifies a target, patent analysis can address additional issues such as: is the target's technology as good as expected?

Is the target's technology focus compatible with or complementary to the acquiring company? Who are the key scientists/inventors, and will they stay with the merged company? Is the company priced fairly considering its relative technological ranking among its competitors, and their market values?

Figure 14 (based on a consulting study done several years ago) shows a pair of citation stick diagrams for a small niche technology company we will call company X. Each stick represents a single patent that has received 10 or more citations from later patents. The figure thus indicates the subset of the company's patents that are likely to be the most technologically interesting. Notice that, by removing a single key inventor, many highly cited patents disappear, indicating that this individual was responsible for many key inventions in the company.

Company X was a subsidiary of parent company A; company A sold the subsidiary X to company B. Subsequently, company B became worried that they had purchased a technological shell, with a weak R&D laboratory. CHI was engaged to assess the technology quality of company X. Figure 14 was created as part of the analysis. When it was found that a single inventor drove the laboratory, it was decided to call the firm to make contact with him. Company X informed CHI that he no longer worked with them. Company A, which was company X's original parent company, was then called. As suspected, Company A had moved the inventor to the parent company prior to the sale to Company B. Company B subsequently resold company X at a substantial loss. The moral therefore is that a thorough patent evaluation should be done before an acquisition is completed.

6. Company valuation

Patent analysis can also be used to estimate the value of a company, based on the company's patent estate. The disparity between book values of publicly traded companies and their stock market valuations has increased steadily in recent years according to Baruch Lev [11]. To quote Lev: 'the mean M/B ratio of the S&P 500 companies (the largest 500 companies in the USA) has continuously increased since the early 1980s, reaching the value of ~6 in March 2001. This suggests that, of every $6 of market value, only one dollar

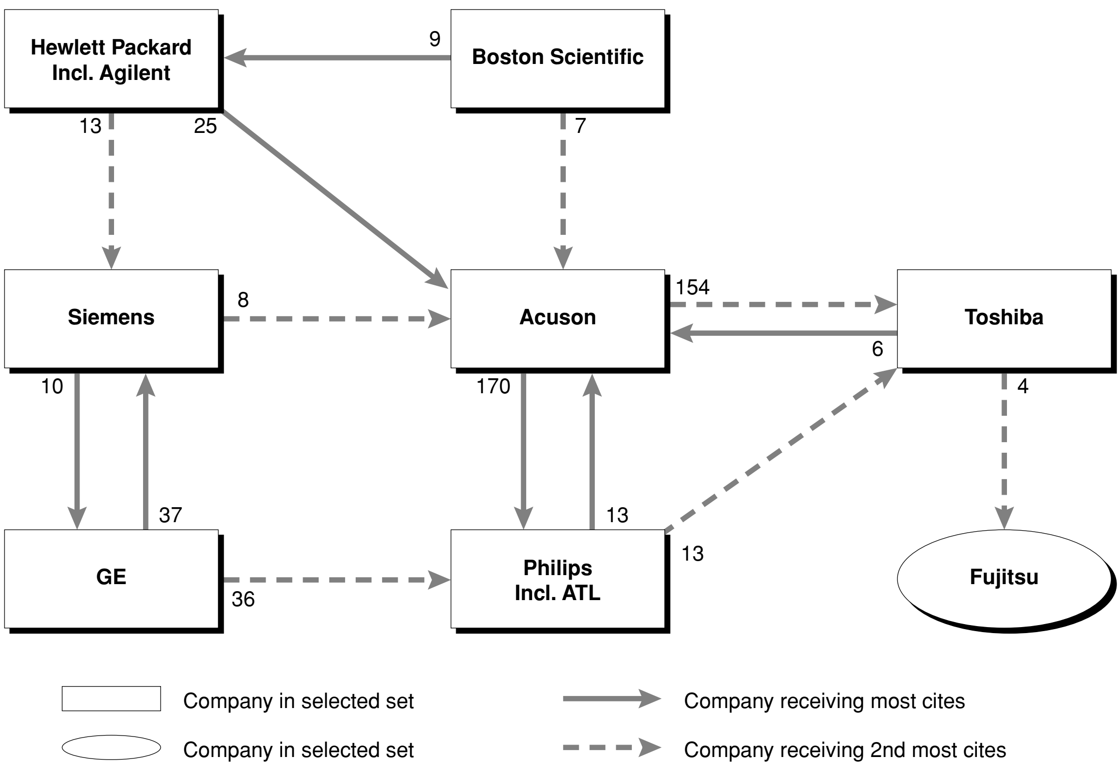

Fig. 13. Acuson is at the centre of the latest developments in ultrasound technology (linkage map shows citation relationships between companies).

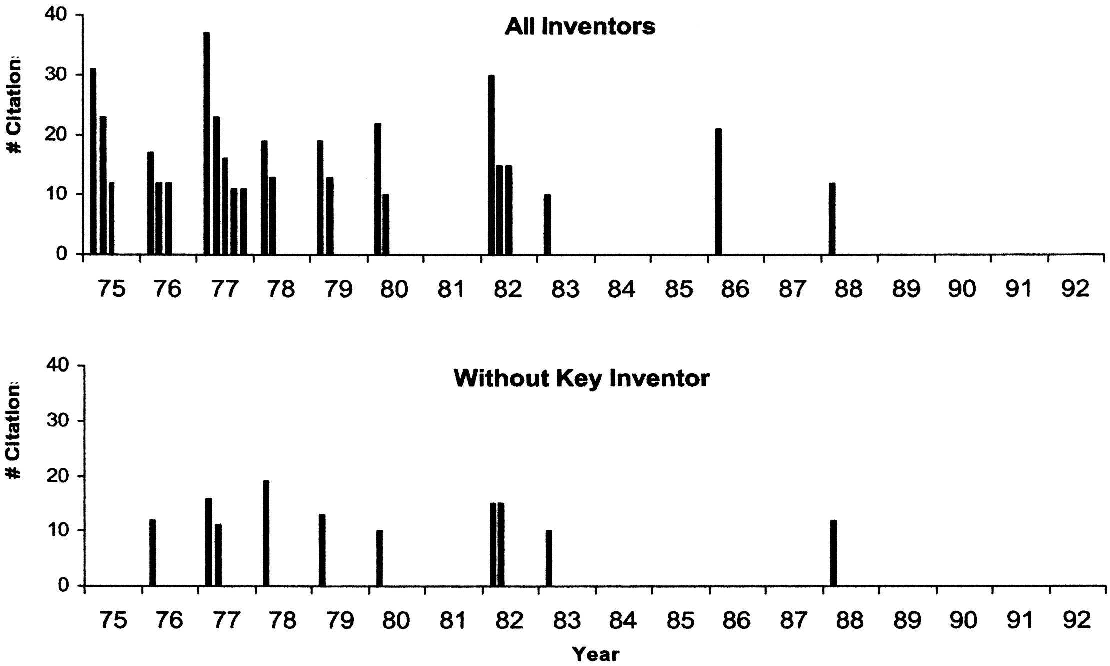

Fig. 14. Highly cited patents by year for Company X.

appears on the balance sheet, while the remaining five dollars represent intangible assets' [11].

Although this is a slight oversimplification, the very substantial value of intangible assets (e.g. patents, trademarks, brand recognition) is not accounted for on the balance sheets of most companies. It should be noted that the link between company value and intangible assets is starting to be widely recognized. Even a cursory review of all of the literature on this topic is well beyond the scope of this article. There are more than 30 books in print with Intangible Asset or Intellectual Capital in their titles, plus numerous articles and conferences on the topic.

For example, Merck (at the time of this writing – December 2001) trades at nine times its book value. The argument goes that 89% (8/9ths) of Merck's value is determined by intangible assets, rather than its plants, equipment and other assets on the books. These valuable but intangible assets include strong research, patents, established brands, good will and marketing.

Estimating the value of a company from its patent estate is therefore no less reasonable than valuing a company based on its balance sheet. Often it is more reasonable. Patrick Thomas [12] has developed a methodology for valuing companies based on the quality of their patent portfolios. This methodology compares a company's actual market-to-book (MTB) valuation with a Tech-Score MTB based solely on the quality of its patent portfolio. Using this idea, an analyst can define whether a company is overvalued, based upon its technology (i.e. Actual MTB exceeds Tech Score MTB), or undervalued (i.e. Tech Score MTB exceeds Actual MTB).

Figure 15 shows the forecasting power of this technique. This figure is based on the idea of defining companies as undervalued or overvalued, and then determining whether their market-to-book valuation two years later has changed in the direction indicated by the model. The market-to-book valuation of undervalued companies should have risen relative to the overall market, while the valuation of the overvalued companies should have fallen relative to the market. The line marked 'Overall' in Fig. 15 measured the strength of the stock market. In a strong market, a high percentage of companies experience increased market-to-book valuations, due to increases in their stock price. For example, just over 70% of the companies in the model at the end of 1990 had higher market-to-book valuations two years later. This suggests that the stock market was on an upward trend during that period. However, if these companies are split into two groups – undervalued and overvalued – the forecasting power of the technique becomes clear. Over 80% of the companies defined as undervalued at the end of 1990 had a higher market-to-book value two years later, compared to only 60% of overvalued companies.

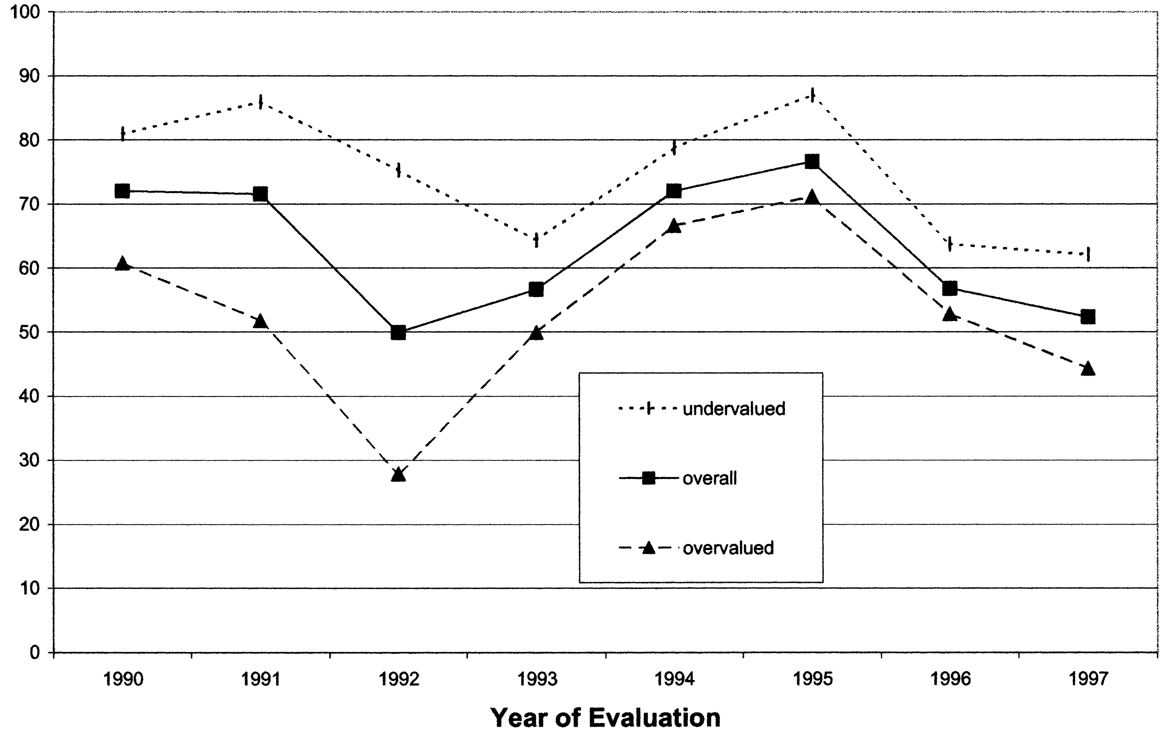

Fig. 15. Companies undervalued based on patent scores are more likely to experience increased market-to-book: percentage of companies with increased market-to-book two years after patent evaluation.

This pattern is the same throughout the last decade. At the end of each year, companies are defined as undervalued or overvalued. As Fig. 15 shows, each year the percentage of undervalued companies with higher market-to-book valuations two years later is greater than the percentage of overvalued companies with increased market-to-book value two years later. The pattern occurs in strong markets (where a high percentage of companies increase market-to-book value) and weaker markets (in which a lower percentage of companies increase market-to-book). This suggests that the technique is a useful tool for identifying companies that are currently undervalued or overvalued by the stock market.

When determining whether a company is over- or under-priced, we implicitly identify a target price for the company based on patent indicators, known as the Tech-Score Market-to-Book ratio or Tech-Score MTB. Table 3 is from a recent study that examined whether Glaxo paid too much for SmithKline. The figure shows the Actual MTB and Tech-Score MTB for the eight largest pharmaceutical companies as of 31 December 1999. It reveals that Glaxo and SmithKline were trading at $27.37 and $12.40. Based on their Tech-Score Prices, Glaxo should have been trading at $6.72, and SmithKline at $3.51. Both companies were therefore overvalued, as were the other six pharmaceutical companies in the study.

The interesting issue, however, is the relationship between the Tech-Score valuations of the two companies, and not the actual valuations, since the proposed merger between Glaxo and SmithKline is to be based on a stock swap. Table 3 shows that, in terms of the quality of their patented technology, one SmithKline share is worth 0.5223 ($3.51/$6.72) Glaxo shares. Under the terms of the merger, each SmithKline share is valued at 0.4552 Glaxo shares. This suggests that Glaxo was able to purchase SmithKline shares at a relative discount because of its own inflated purchasing power. Therefore, based upon the relative quality of their patent portfolios, Glaxo did not pay too much for SmithKline. It paid too little.

7. Competitive intelligence

One of the most frequent applications of patent analysis is for competitive intelligence (CI). Many techniques described above are combined to answer CI questions such as: what are my competitors up to technologically?

Table 3
Examining technology market-to-book values relative to actual market-to-book values

	Actual MTB 31 December 1999	Tech MTB 31 December 1999	Percentage overvalued	Actual price 31 December 1999	Tech price 31 December 1999
SmithKline Beecham	13.81	3.91	353	12.40	3.51
Glaxo Wellcome	22.63	5.56	407	27.37	6.72
Merck & Co.	11.3	4.05	279	78.63	28.18
J&J	6.35	3.56	178	86.06	48.25
Novartis	5.31	3.92	135	739.98	546.28
Bristol–Meyers Squibb	13.6	3.76	362	66.25	18.32
American Home Products	12.47	3.05	409	47.06	11.51
Pfizer	16.11	3.64	443	36.19	8.18

ADR stands for American Depository Receipt, which is a stock traded in the USA, but representing a number of shares in a foreign corporation. In this table ADR values are converted to actual shares (e.g. one SmithKline ADR is five shares).
MTB stands for market-to-book ratio. See text for details.

Are they developing recent technology unrelated to their current product line? If my company moves into technology X, who else will we have to compete with? Are there specific inventors my company should be tracking? Are there new companies entering my industry? What types of patents are my competitors allowing to lapse? It is easy to see how some of the techniques previously described can work to answer these types of questions. For a discussion of the role of patent indicators in CI see References [10, 13].

8. Conclusions

When used correctly, patent analysis provides a powerful tool with applications at the strategic, tactical, and individual invention level. This paper has discussed numerous ways in which analysts use patent analysis, including examples at the patent level such as intellectual property management, to the strategic and tactical level where hundreds or thousands of patents are analysed. Examples of the latter included competitive intelligence, M&A targeting and due-diligence, company valuation and portfolio management.

Note: all the figures included in this paper are owned by CHI or Mogee Research and Analysis.

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Appendix: brief review of studies discussing the relationship between high citations and technological importance

In this section, we take a moment to review the evidence that patent indicators, and patent citation indicators, are a useful technique for assessing the quality of an organization's patented technology. This review is a subset of a more thorough review in Narin [14]. Another thorough review on the topic can be found in Oppenheim [2].

The main point of this section is that there is compelling evidence that high citation rates are associated with the importance of the technological discoveries in the patents being cited. This does not guarantee that every highly cited patent is of importance, or that a patent that is not highly cited is of little importance. It does argue, however, that a company with a portfolio of highly cited patents is more likely to be technologically successful than one whose patents are cited less frequently. In addition, there is emerging evidence that citation indicators are indicative of, and in some cases predictive of, company technological, economic, and stock market success.

Basics of patent citation analysis

When a patent is published or issued, it typically contains several (eight is the average for US patents) references that link the patent to the earlier cited prior art, and limit the claims of the new patent. They point out where essential and related art already exists, and delineate the property rights of the invention as determined by the patent office in question.

This is an oversimplification of course, and there is great variation in the referencing rules for the various patent systems of the world. In the US system it is the applicant's responsibility to identify all relevant prior art upon which the new invention improves, or which limits the claims of the current invention. The patent examiner may add to or subtract from the list of references supplied by the applicant. The patent examiner is the final arbiter of what is included, but he is 'not called upon to cite all references that are available, but only the best' [15]. The European patent system is quite different, with none of the prior art references cited by the applicant. We will not delve into patent law of the more than 40 significant national and international patent systems, but only point out that, before doing a patent citation analysis, it is important to define what a citation means in the particular patent system being analysed.

When the referencing pattern is turned around, and all of the subsequent citations to a given patent are tabulated, one obtains the fundamental information used in patent citation analysis, namely, a count of how often a given patent is cited in later patents. These distributions tend to be very skewed: there are large numbers of patents that are cited only a few times, and only a small number of patents cited more than 10 times. For example, for US patents issued in 1988, and cited in the next seven years, half the patents are cited two or fewer times, 75% are cited five or fewer times, and only 1% of the patents are cited 24 or more times. Overall, after 10 or more years the average number of cites per patent is around six.

Validation studies

There is no official standard by which the importance of a patent may be judged except, perhaps, for the Federal Court's designation of 'pioneering patents' (discussed below). Therefore, most of the studies of citation frequency and patent importance are based upon the opinions of knowledgeable scientists or engineers, or correlations with non-patent measures. Below is a chronological history of validation studies. It is by no means exhaustive, but it shows that patent citation analysis has roots that go back to at least the 1960s.

One of the earliest studies that looked at patent citations as a way of finding important patents was done by Reisner [16] at IBM, who experimented with the use of citation analysis to find key patents. By tracing the references from one patent to another, Reisner found 43 of 60 patents she was looking for.

Computerized citation data covering all US patents first became available in 1975. In the following year, in the Sixth Technology Assessment and Forecast report [17], the Patent and Trademark Office tabulated the patents that were most highly cited and suggested that 'the number of times a patent document is cited may be a measure of its technological significance.'

In 1981 CHI, in a study sponsored by the NSF [18], showed that patents associated with the IR-100 award received twice as many citations as a control set of patents of the same age and in the same technologies. The IR-100 award, established by the journal *Industrial Research and Development* [19], 'honors the 100 most significant new technical products – and the innovators responsible for them – developed during the year.' Another citation validation study was carried out by Worcester Polytechnic Institute students and the US Patent and Trademark Office. The last sentence in the abstract explains the key result. 'The results were found to support the hypothesis that highly cited patents are important' [20].

In 1990, Manual Trajtenberg [21] found that patent citation counts were correlated with an independent measure of the value of an innovation, measured as a function of price and product attributes, called by economists the social gain stemming from the innovation. He also pointed out the significant limitations of simple patent counts as a measure of technological strength.

A validation study of patent citation analysis within an industrial context was carried out by CHI Research in cooperation with Eastman Kodak Laboratories [22]. In that study, a collection of nearly 100 Kodak patents in their core area of silver halide technology were divided into sets of 16 each, and the sets given to senior laboratory staff for evaluation. The Kodak evaluators were senior intellectual property staff, senior laboratory management, and senior laboratory scientists. In the case of scientists, the patents they were given to rank were screened, to make sure that they did not rank their own patents. Each person was asked to rank the patents based on how much each had changed the state-of-the-art in the field of the invention.

The results showed that whether a patent is cited one, two or three times does not seem to make much difference in the peer ranking. However, patents cited more than five times were ranked far more highly by the Kodak staff. Of the 15 respondents in the study, eight gave this group of patents the highest average rating. This is a statistically significant result given that, using the binomial model, the probability of this happening randomly is 0.0002.

A 1996 study [23] examined citation frequencies of three different categories of special patents: patents listed in the National Inventor's Hall of Fame, patents of Historical Significance in a list prepared by the US Department of Commerce for the USPTO bicentennial, and patents that had been adjudged as pioneering patents by the Federal District Court. The term pioneer patent refers to patents that the courts have deemed to be so groundbreaking that they deserve a wide interpretation of their claims.

The study found that pioneering patents are cited almost seven times as often as expected; Hall of Fame patents are cited more than six times as often as expected, and historically significant patents almost 2.5 times as often as expected. Moreover, the results were not driven by a few highly cited patents within each set; in fact, of all the patents in all three sets, only one was cited fewer times than expected.

A 1998 study [24] used an interesting technique to examine importance versus citation frequency. This study was based on patents on which profitability information – that is the private value of the patents – was obtained. The authors considered only patents for which all the fees had been paid to keep the patents in force in Germany for the full 18 years of the patents. They queried the owners of those patents as to the asset value of the patent – essentially asking what is the smallest amount they would have been willing to sell this patent to an independent third party for in 1980? In the German patent system the two patents in the highest value category were much more highly cited than the others. In the US patent system the patent citation frequency of the patents with an estimated value of $20 million or above was substantially higher than that of the patents with lower estimated values.

In 1999, Thomas [25] found a correlation between patent citation counts and positive renewal decisions. Essentially, he found that patents for which the renewal fees had been paid were more highly cited then their counterparts that were allowed to lapse.

Also in 1999, Zhen Deng *et al*. [26] used a number of patent citation indicators to predict stock performance. Other studies related to using citation indicators for choosing stocks include Breitzman and Narin [27], which showed that a portfolio of stocks picked based on patent indicators outperformed the S&P 500 three-fold in a 10 year period. Finally, Thomas [12] showed a patent indicator-based method could identify stocks that are under-valued based on the quality of their technology.

Increasingly, economists have begun to use measures based on patents and their citations as indicators of technological output. Only a few are mentioned here. Hall *et al.* [28] explored the contributions of R&D spending, patents and citation-weighted patents to measures of the financial market valuation of the firms that own the patents for more than 4800 US manufacturing firms. They found that citation-weighted patent stocks were more highly correlated with market value than patent stocks themselves because of the high valuation placed on firms that hold very highly cited patents. Jaffe *et al.* [29] surveyed 1993 US patentees regarding the importance of their inventions, the extent of their communication with other inventors, and the relationship of both importance and communication to observed patent citations. They found a significant correlation between the number of citations a patent received and its importance (both economic and technological) as perceived by the inventor. Lanjouw and Schankerman [30] investigated the characteristics of litigated patents. They found that, compared with a random sample of US patents from the same cohorts and technology areas, patents that were cited more often were considerably more likely to be involved in litigation.