The S. Neaman Institute for
Advanced Studies in Science and
Technology, Haifa, Israel

Fraunhofer Institute for Systems and
Innovation Research
Karlsruhe, Germany

Technometric Benchmarking: Toward an Integrative Operational Model for Management of Technology and Innovation in Science- Based Corporations

Annual Report on Completion of the Second Year of Research
under Support of the German-Israel Foundation Grant for
1997
G.I.F. Research Grant No. I-339-009.04/94

December 1997

Principal Investigators:

Prof. Shlomo Maital, The S. Neaman Institute for Advanced Studies in Science and Technology, Technion - Israel Institute of Technology

and

Dr. Hariolf Grupp, Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany

The S. Neaman Institute for
Advanced Studies in Science and
Technology, Haifa, Israel

Fraunhofer Institute for Systems and
Innovation Research
Karlsruhe, Germany

Technometric Benchmarking: Toward an Integrative Operational Model for Management of Technology and Innovation in Science- Based Corporations

Annual Report on Completion of the Second Year of Research
under Support of the German-Israel Foundation Grant for
1997
G.I.F. Research Grant No. I-339-009.04/94

December 1997

Principal Investigators:

Prof. Shlomo Maital, The S. Neaman Institute for Advanced Studies in Science and Technology, Technion - Israel Institute of Technology

and

Dr. Hariolf Grupp, Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, Germany

Shlomo Maital

Contents:

APPENDIXES

1. Abstract

Overall objective of our project: "...to equip managers of technology in science-based companies [in Israel and in Germany] with tools that can help their firms become more innovative and competitive". (from our Research Proposal).

In this project, we are developing an integrated "toolkit" of quantitative benchmarking models, covering each aspect of the innovation process from R&D through innovation, production and marketing. This toolkit is based on the general framework of "technometrics" - measurement and comparison of products and services, feature by feature.

2. Progress Related to Time Schedule

The time schedule for 1997 consisted of four main tasks

- creating of marketing module
- data collection
- preparing the conference on Innovation
- creating the manufacturing module

2.1 Creation of the marketing module

Our activity in this area led to two working papers:

a) Optimal Incremental Innovation: Integrating Marketing & R&D.

b) Global Integration of Marketing & R&D.

(a) has been accepted for publication by R&D Management.

(b) was commissioned by Prof. Arch Woodside, editor of Handbook of Industrial Marketing, and will likely be published in that journal.

In addition: Prof. Woodside has commissioned a survey article on Quantitative Methods of Benchmarking, which is currently in preparation, and will likely be published as well in the Handbook of Industrial Marketing.

Another working paper is in the initial stages: "Partitioning Market Value between Product Attributes and Brand Name", (see attached abstract).

2.2 Data collection

Our data collection comprises largely detailed interviews and case-study work with selected high tech companies. We completed this work by mid-1997, and now have a "stable" of some 9 companies to which we are applying our technometric model. We added to our original list another case: IBM Haifa Research Lab, and its Webcutter internet product. This case has already been written.

2.3 Preparing the conference on Innovation

This conference, held May 29, 1997, was held at an unusual site -- the Iskar Ltd. installation at Tefen, Galilee -- and included tours of Iskar's plant. It was well attended, with a high level of papers presented, and combined two GIF projects: our own, and the project on innovation diffusion (Shefer and Koschatzky).

2.4 Creation of the manufacturing module

We are integrating a model known as Quality Function Deployment (QFD) (Hauser, 1987), into our technometric toolbox. This work is in its initial stages. At present, we have a detailed example of QFD as applied to design and production of a medical imaging camera. We are working on a formal QFD model, in quantatitive (mathematical) form -- much of the QFD literature is qualitative and imprecise. We anticipate this module will be completed by Spring 1998.

2.5 Field test of modules (not included in the original plan)

Part of our original Work Plan and Time Schedule was preparation of a Field Manual for our technometric integrated model.

We have now decided to develop software, in place of a manual. An initial version of that software, known tentatively as featureMetrics c , is now complete and ready for beta-site field testing. We have been offered cooperation by the Director-General of the Israel Association of Electronics Manufacturers. We will also explore beta-sites in Germany -- perhaps at Siemens. The software, of course, will be accompanied by an explanatory manual -- but will be simple, straightforward and "friendly", and largely menu-driven.

2.6 Production module (not included in the original plan)

(See above -- testing of our model will largely be implemented through field trails of our software, with close oversight by the principal investigators, workshops for managers in beta-site firms, etc.).

2.7 Book (not in original plan).

We plan to write a book on our new approach, aimed at engineers and practitioners in the field. The book will be in essence our final report. An initial outline of the book is in preparation.

Activities:

a) Publications: Two papers were accepted for publication:

[1] Optimal Incremental Innovation: A Mathematical Programming Model for Integrating R&D and Marketing. Forthcoming, Research Evaluation.

[2] Identifying Sources of Value in a Capital Goods Market: R&D Management in Industrial Sensors. Forthcoming, R&D Management.

These two papers were also issued as Discussion Papers of the Tinbergen Institute, Erasmus University, Rotterdam, Holland.

b) Awards:

"Identifying Sources of Value..." was selected for the Best Paper Award at the IAMOT International Conference, held at Gotheberg, Sweden, June 25-27, 1997. Several hundred papers presented at the conference competed for this award.

c) Conferences:

i) Grupp, Maital and Frenkel organized an international conference, held at Iskar ltd., Tefen, Galilee, Israel, May 29, 1997, on "Innovation: Technology Forecasting, Assessment, Strategy & Regional Policy".

ii) Grupp presented "Optimal Incremental Innovation..." at the IAMOT Conference, Gotheberg, Sweden, June 1997.

iii) Maital presented the case study: Integrating R&D and Marketing: The Case of 'Webcutter' to : "New Dimensions in Global Innovation", Workshop held at the Institute for Technology & Enterprise, New York City, Sept. 25, 1997.

iv) "Optimal Radical Innovation" was accepted for the Program of the International Association of Management of Technology, to be held in Orlando, Florida, Feb. 10-16, 1998. Dr. Grupp will present the paper.

d) Lectures:

- Maital gave a seminar on "Optimal Incremental Innovation" at Erasmus University - Tinbergen Institute on Oct. 18, 1997.
- Maital will present the same paper at the Penn State-Technion Seminar on Industrial Engineering, on Jan. 4, 1998.

e) Working papers:

[3] H. Grupp & S. Maital. "Partitioning Productivity Growth Between Capital-Deepening and Technological Change, at the Firm Level", first draft.

[4] H. Grupp and S. Maital. "Optimal Radical Innovation". First draft.

[5] A. Frenkel, H. Grupp, S. Maital. "Benchmarking Technological Change in Science-based Products: The Case of Biodiagnostic Kits", paper in progress.

[6] Frenkel, Grupp, Maital, Shalit. "Integrating Quality Function Deployment in a General Benchmarking Model: The Case of MRI Cameras". Work in progress.

[7] Frenkel, Grupp, Maital. "Integrating Adaptive Conjoint Analysis in a General Benchmarking Model". Work in progress.

[8] H. Grupp, S. Maital. Quantitative Benchmarking Models. In preparation for: Advances in Industrial Marketing.

[9] Integrating R&D and Marketing: The Case of 'Webcutter' (case study), for inclusion in Handbook of Marketing.

e) Joint Visits:

Maital visited Karlsruhe, Germany, Oct. 8-12, 1997.

Grupp visited Israel on May 27-30, 1997.

f) Software:

An initial version of Technometric Benchmarking software has been developed, written in Visual Basic within an Excel environment.

List of Research Papers:

[1] A. Ben Arieh, H. Grupp and S. Maital. "Optimal Incremental Innovation: Integrating R&D and Marketing". Accepted for publication, Research Evaluation. (Completed in 1996, revised in 1997)* .

[2] H. Grupp, S. Maital. "Interpreting the Sources of Value in a Capital Goods Market: R&D Management in Industrial Sensors". Accepted for publication, R&D Management. (Completed in 1996, revised in 1997)* .

[3] H. Grupp & S. Maital. "Partitioning Productivity Change at the Firm Level". First draft.

[4] H. Grupp and S. Maital. "Optimal Radical Innovation". First draft.

[5] A. Frenkel, H. Grupp, S. Maital. "Benchmarking Technological Change in Science-based Products: The Case of Biodiagnostic Kits", paper in progress.

[6] Frenkel, Grupp, Maital, Shalit. "Integrating Quality Function Deployment in a General Benchmarking Model: The Case of MRI Cameras". Work in progress.

[7] Frenkel, Grupp, Maital. "Integrating Adaptive Conjoint Analysis in a General Benchmarking Model". Work in progress.

[8] H. Grupp, S. Maital. Quantitative Benchmarking Models. In preparation for: Advances in Industrial Marketing.

[9] Integrating R&D and Marketing: The Case of 'Webcutter' (case study), for inclusion in Handbook of Marketing.

[10] Frenkel, Grupp, Maital. "Partitioning Market Value Between Product Attributes and Brand Name: A Data Experimental Approach".

---

* Mentioned in 1996 annual report

Comments:

1. We have expanded our "innovation" module to include two different cases: optimal "incremental" innovation, which involves improvement of an existing product or service in an optimal fashion, and optimal "radical" innovation, which involves creating new product features which did not previously exist.

2. We added an additional section to our research, not mentioned in our original Research Proposal. This section revisits our first GIF project's data, and uses our technometric benchmarking model to measure changes in product quality over time (for biodiagnostic kits). We are also revisiting our sensor database, and recontacting participating firms, to update our data and, for sensors as well, measure technological change for various models. This new research provides a "dynamic" dimension to our research, which until now has focused largely on cross-section "snapshot" analysis at a given point in time.

3. Aspects of Cooperation among the Israeli and German Team:

Dr. Hariolf Grupp visited the Neaman Institute during May 28-30, 1997, together with a colleague. He participated in the Workshop organized jointly with Maital, and held at Tefen, in the Galilee. During his visit, he and Maital worked on several joint papers.

Prof. Maital visited Fraunhofer-ISI during Oct. 8-13, 1997. During this visit, Grupp and Maital worked on working papers: [3] [4] [7] [8] [9].

Grupp and Maital are in constant electronic-mail contact. Exchange of papers and ideas by email has proven highly effective and efficient.

Appendix A - Papers.

Interpreting the Sources of Market Value in a Capital Goods Market: R&D in Industrial Sensors

Abstract

This paper presents an integrated model for evaluating purchasers' perceptions of science-based products. The model combines a new approach to benchmarking, known as technometrics, that provides a quantitative profile of a product's key attributes, with direct and indirect methods for measuring buyers' perceptions regarding the relative importance of product attributes as a source of value. A new measure for the demand orientation is proposed, which shows the extent to which a product's „supply“ of characteristics matches the „demand“ for them in the market place. The model is illustrated using several types of industrial pressure sensors. The paper also demonstrates how the integrated model may be made effective for quality function deployment (QFD) during the R&D phase.

1 The sensor market as an innovation and quality strategy assignment

Companies working on innovations on a particular market tend to have commonality of scientifico-technical opportunity and, because of the specific nature of the technology concerned, the resulting potentiality for appropriation of innovation rents, see, e. g. Cohen (1995). This paper tries to examine the sensor market, a „conventional" market with monopolistic competition in which knowledge generation is largely uncoloured by state influence. It features both large and small companies, universal and special suppliers. At the same time it has something to do with modern science and is a market for capital goods.

The sensor market has been expanding over the last decade; characteristic growth rates for sensor sub-markets are between 10 and 30 per cent. The world market for sensors is currently worth over 5 thousand million US $ per annum; methods of calculation and the estimates however deviate very widely. By the year 2001, as Arnold (1991) notes, growth rates are expected to be 8 per cent per annum; the 2001 market volume could be 43 thousand million (43 US Billion) $. The uncertainty over sensor estimates stems directly from arbitrary drawing of sensor demarcation lines: Should supply lines, decoding electronics or calibration units be included or excluded? The price of a complete sensor system can deviate from that of the sensor element contained in it by one order of magnitude.

The sensor market is highly *segmented.* An overview by Grupp et al. (1987, p. 234) lists nigh on 90 measurands for which sensors are available commercially or which are in process of development. The number of types of sensors (in terms of product variants) however is clearly even larger since for each measurement parameter there are several if not many measurement processes available. Internationally, currently a total of approximately 10,000 different types of sensor are on offer; the number of brands is incalculable. In OECD countries, there are approximately 2,000 potential suppliers of sensors, most of whom are offering their own products.

Marked segmentation of the sensor market imposes one prime requirement on the R&D management of innovators: they must be stronger than others in *systematic early warning functions* and set up a strategic technology management. This is a defining parameter specific to the sensor industry and common to innovation behaviour in the intersectoral comparison. It would therefore seem apposite, prior to analysing technical properties (Section 4) and demand preferences (Section 5), to set out one or two general considerations for technology management. According to the above analysis of the basic structures of the sensor market, the corresponding technology management in the intersectoral comparison is problematical from both aspects: technological analysis, owing to the many technical processes and measurement parameters used for sensors is just as complex as formulating a competitive quality strategy taking segmented markets into account.

2 A new benchmarking concept

At the beginning of the eighties a series of „metrics" for evaluating and comparing technological sophistication and quality were proposed. What was coined „technometrics" in 1985 is a procedure designed along Lancaster's (1991) consumer theory and is based on the observation that every innovative product or process has a set of key attributes that defines its performance, value or ability to satisfy customer wants. Each of these attributes has a different unit of measurement. Problems then arise in aggregating attributes to build a single quality index. Mathematical details of the general procedure are not discussed here as they may be found in Grupp (1994). Suffice to say that the technometric indicator surmounts this difficulty by converting each measured attribute into a [0,1] metric, enabling construction of weighted averages, etc., and permitting comparisons across products, firms, industries and countries. The „0" point of the metric is set as the technologically standard attribute; the „1" point is set as the most technologically sophisticated attribute in existence at a given point in time. The preferences may be derived from utility functions, by introspective or market observation, from expert knowledge or via hedonic prices.

When conducting a technology-oriented competition survey, a relative competition analysis is recommended, cf. Backhaus (1992, pp. 135 onwards) or Shillito (1994, p. 52 onwards). Usually, this is done by assessing the own position by reference to those of the relevant competitors. Owing to the lack of suitable metric data, competitor information is graphed qualitatively (e. g., „low" versus „high"). The technometric indicator is available, in competitor analysis, as a substitute for qualitative scales if the corresponding data are available from the rival company.

From competitor observation, portfolios can be compiled which just like financial business portfolios tend to be referred to in R&D management circles as *technology portfolios*. The use of portfolio procedures for technology evaluation is considered the best method in the field of corporate R&D management, see, e. g., EIRMA (1985, p. 27). In view of the few comments that can be made about industrial technology management, product quality measurement is still the final resort. The latest keyword of „benchmarking" is nothing other than the systematic comparison of the quality of products and services of a company in relation to those of the leading competitors, following Camp (1989) or Shillito (1994). Interest in benchmarking has grown enormously over the last 10 years. Technometrics applied in business management is nothing more than standardisation of product quality in terms of technical properties. Even now, technometric procedures still do not feature in benchmarking literature. First applications may be found in Shoham et al. (1996).

3 Data on technical characteristics of pressure sensors

In this Section, the problem of pricing of technically valuable goods and the effect of technical characteristics is tackled. The sensor market is thus regarded as a market with free and floating prices dictated by supply and demand factors. The first step must be to itemise the most important technical properties of sensors and then extract a selection from the wealth of conceivable measures. Koschatzky and others (1996) in a wide-ranging empirical survey were concerned primarily with pressure and temperature sensors (in addition to those for measuring acceleration, force and relative humidity). The inquiry related to earlier technometrics by Grupp et al. (1987) on sensors which reflected the 1986 market.

The primary data analysis thus involves large-scale gathering of exhibition material at the largest sensor fair in the world where not only exhibits, as is customary, are displayed but also specification sheets with the appropriate data.[1] Quite apart from the field survey conducted other companies were consulted so that in all 286 companies were approached in one way or another. Of these, 151 yielded comparable detailed information. Koschatzky and Frenkel (1996) also conducted 10 personal interviews with Israeli companies so that in all data from 160 sensor firms was obtained. When considering the breakdown of companies according to country, it should be remembered that European and primarily German speaking countries predominate since the fair in this year took place in Germany. Apart from companies from the United States and Israel, however, Japanese companies were also represented in the random sample.

The technical properties selected and compared were established by specialist discussions in the earlier investigation of the sensor market. In so doing, it became apparent that different specifications are important for different measuring principles and tasks. To illustrate the data, in this chapter only pressure sensor analysis is spotlighted. Conceptually, if four products are deliberately chosen from the databank and the technometric indicators calculated, then a technological or characteristic profile will be obtained as per Figure 1. In such case, it should be noted that for certain products, isolated numerical values are missing (not divulged by the manufacturer).

1 This is the SENSOR Fair which took place in May 1991 in Nuremberg.

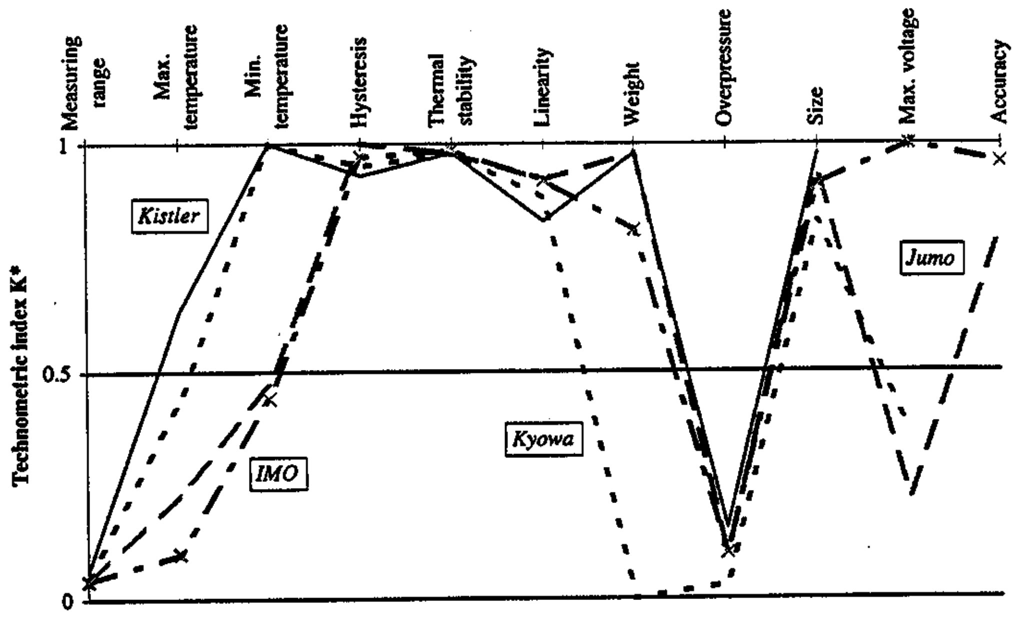


Figure 1: Technometric characteristic profile of four selected pressure sensors (1991).

4 Technical quality and hedonic prices

For the sensor market, which, according to the assessment in Section 1, can be construed as being functional, i. e. intensively competitive and efficient, an empirical relationship should be discernible between the quantitatively measured attributes of the product and product prices. It should be possible to solve the problem by multiple linear reggression (OLS), the dependent variable being market price and the independent variables being product properties. Thus, the absolute values of the coefficients show what value the market assigns to this property. The proposed approach has been considered sporadically in R&D management literature here and there as far back as the 60's and linked to the hedonic price concept, see Griliches (1961, 1971) and Chow (1968). The new literature encompasses Saviotti (1985), Trajtenberg (1990) and Dorison (1992).

In the regression analysis, it was felt expedient to omit sensors with many missing data. The hedonic price determination therefore related to 68 sensors and eleven properties. The regression calculation can account for precisely half of the variance ($R^2 = 0.50$). This is open to different interpretations depending upon viewpoint. On the one hand, this means that half of the price variation alone is explicable in terms of the physico-technical properties of the products. On the other hand, likewise one half is attributable to price variance which cannot be explained in terms of quality improvement but relies on the manufacturer's reputation or upon various marketing endeavours on service, maintenance, established practices or can be traced back to other preferences.

Of the eleven variables only two are significant. They originate from application of stepwise regression in which explanatory variables are arranged (according to an F - test) in order of their ability to raise the variance explained. The maximum coefficient occurs for the variable for maximum temperature; it is almost twice as great as the next largest coefficient for the weight. It can therefore be assumed that the maximum contribution towards price elucidation is made by the *maximum temperature* and *weight* of the sensor. These are the two decisive quality variables. Interestingly, both variables, on their own, virtually account for the entire quality-dictated price variance ($R^2_{adj} = 0.46$ in comparison to $R^2 = 0.50$ for all variables).

The hedonic price investigation for pressure sensors reveals that of the eleven technical properties two account, straight away, for the quality-determined part of sensor pricing, in all practically half of the price variation. The maximum permissible temperature has a direct bearing on the application potential in the industrial field. The supposition that lightweight versions would be among the most important consumer preferences does not hold. Higher prices are currently commanded by heavier weight sensors on the sensor market. This is presumably connected with the idea that the heavier units are more durable and can assimilate greater stress under extreme conditions.

The findings confirm the Lancaster (1991) new consumer theory according to which prospective customers are not interested in the goods as such but in their properties. From the sensor market analysis, this comment can be extended to: *„a particular handful of properties"*. It has thus been shown that for pressure sensors in 1991 questions of material saving or use of lighter materials are still not considered to be prime characteristics although this is generally postulated in literature for technical advances in sensors. Clearly, the properties associated with heavier units take precedence (durability, stability, etc.). A particularly lightweight sensor produced at high production costs which in all other respects does not differ from rival products commercially will not succeed in defraying the higher production costs. The only advice that could be given to a particular company which is bent on precisely this innovation is to „tune into the market" and at any rate so long as the demand for dearer lightweight sensors continues to be inadequate to refrain from embarking on a corresponding innovation venture. The use of hedonic prices in connection with technometrics appears to be a valuable analytical instrument for microeconomic as well as for business management use. Admittedly, there are more direct ways in establishing demand preferences which will be discussed in the next Section.

5 Preferences voiced by prospective industrial clients

It is possible to amass information about purchasers' preferences by direct market research. This is the usual and commonest way in practice for missing blocks of information to be obtained on free markets. An entire branch of the economy makes a living from this in market research. So, in order to include „appropriate" data on demand preferences in this context, here, too, a direct market survey has been conducted, see Frenkel et al. (1994). This was done by asking the purchaser of industrial sensors, via a questionnaire, to rate the importance of technometrically determined properties of sensors according to their importance on a scale of between 0 and 10. The same questionnaire was also handed out to sensor manufacturers (R&D personnel, production manager, sales manager) in order to establish the preference rating of their industrial clients as perceived by the manufacturer.

Table 1 shows that, of the 22 quality properties examined, eleven are known from the technometric investigation whilst a further eleven were not considered important to the inquiry. The choice of technometric characteristics was made with the help of the R&D personnel of manufacturers having coherent ideas about the important technical features of their innovative products from the dominant technical design standpoint. From these assessments, sales and marketing departments formulate the corresponding specification sheets which they offer to their customers in the context of general business relationships and supply at fairs, for example. In expert circles, the other eleven properties are to some degree contentious, as far as their importance is concerned, or only represent the individual opinions of outsiders. In some respects, they have been designated by individual prospective clients as „unfortunately defective" in the specification sheets.

Table 1 shows two different things:

- in fact the preferences mentioned for technometric specifications are higher than for the rest,
- and what is perhaps even more interesting, the variances in regard to technometric characteristics are smaller than for the rest.

For the 72 products chosen from eleven innovative companies in six countries which were analysed in greater depth in Section 3, it can be tested to what extent the technical quality of these products is in accordance with the disclosed demand preferences. This is based on the assumption that an efficient company with a good database on demand requirements sets greater store by highly preferred technical features which are reflected in a correspondingly high technometric index. With a view to arriving at a compromise between factor costs and mutually exclusive technical specifications the assumption must be made that the technometric indices for the properties less prized by the prospective purchaser (or as above, the more ambiguous ratings for the entire sub-market) are not endowed with correspondingly high quality. The technometric index must then be correspondingly lower.

By way of illustration, let us look at the best and worst sensor as oriented to demand wishes (Figure 2). The Kyowa (Japan) pressure sensor displays technometric specifications which in terms of the three most important properties (from the demand standpoint) are outstanding, but it is no longer appropriate for „average" preferences. In the next ranking properties, this sensor displays moderate qualities which consumers might accept. Of the 72 products chosen, this unit was the best match to demand requirements, at least, in regard to the most important features.

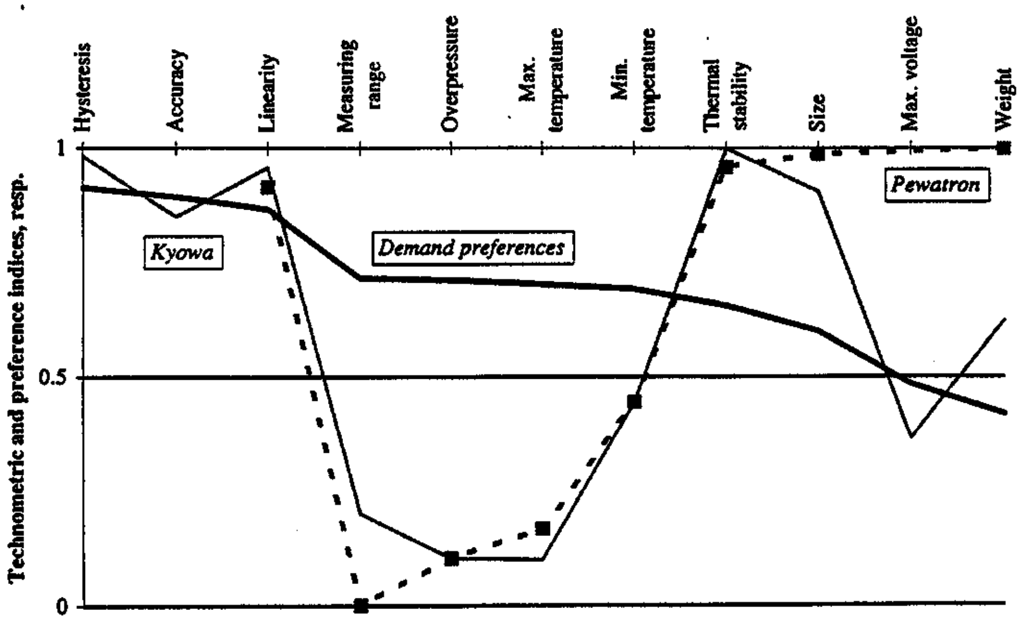


Figure 2: Revealed demand preferences and technometric profiles for two chosen pressure sensors (the technical property configuration shows preferences in decreasing order).

The reverse applies to the Pewatron pressure sensor whose best technometric characteristics materialise in the midst of those properties which users would put at the bottom of the list. This sensor shows high quality in regard to the less important properties. Also worth noting is the fact that the corresponding specifications in regard to both most important characteristics are hardly mentioned by the would-be supplier and might therefore be unknown to the user. This does not appear to be any general corporate marketing strategy because the corresponding data on hysteresis were produced properly for sensors other than the one considered here, from the same manufacturer. Figure 2 gives a visual impression of the technical quality dimension of the two contrasting products in regard to demand preferences, and thus refers to a method Pugh (1990) has described earlier. Whereas in a Pugh matrix scores are being used, here metric scales are involved.

6 Conclusions

Whether the empirical findings proposed hitherto can be corroborated via larger random samples remains to be seen. Against the background of general market equilibrium, a proportion of the resource costs must be attributable to information procurement as it promotes the new microeconomics. As far as that goes, the justified hope remains that the technometric findings for the sensor market can be substantiated by further projects and are not a random event. For QFD, starting points to improve the quality of products under the new technical paradigm can immediately be derived from the technometric portfolio.

In the *R&D management context,* the technometric benchmarking acquires additional importance in identifying niches on capital goods markets. Validation with the aid of market surveys shows that the approach is valid; the characteristics contained in the technometrics index are deemed more important to some prospective purchasers than others. In this respect, this paper can also be viewed as an extension of the common benchmarking literature with relevance for quality function deployment (QFD).

References

Arnold, H. (1991) 'Wachstumsmarkt Sensorik', Markt & Technik, vol. 26, 78-79.

Backhaus, K. (1992) 'Investitionsgütermarketing', München: Verlag Franz Vahlen, third edition.

Camp, R. (1989) 'Benchmarking: The Search for Industry Best Practises that Lead to Superior Performance', ASQC Quality Press.

Chow, G. (1967) 'Technological Change and the Demand for Computers', American Economic Review, vol. 57, 1117-1130.

Cohen, W. (1995) 'Empirical Studies of Innovative Activity', in Stoneman, 182-264.

Dorison, F. (1992) 'Produktbezogener technischer Fortschritt', Ludwigsburg: Verlag Wissenschaft & Praxis.

EIRMA (ed.) (1985) 'Evaluation of R&D Output', Working Group Reports No. 29 of the European Industrial Research Management Association, Paris.

Frenkel, A., Harel, E., Koschatzky, K., Grupp H. & Maital S. (1994) 'Identifying the Sources of Market Value for Science-Based Products: The Case of Industrial Sensors', The International Center for Research on the Management of Technology, Sloan School of Management, MIT, Working Paper WP # 111-94, Cambridge, Mass.

Griliches, Z. (1961) 'Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change', in NBER, 137-196.

Griliches, Z. (ed.) (1971) 'Price Indexes and Quality Change, Studies in New Methods of Measurement', Price Statistic Committee Federal Reserve Board, Cambridge, Mass., Harvard University Press.

Grupp, H. (1994) 'The measurement of technical performance of innovation by technometrics and its impact on established technology indicators', Research Policy vol. 23, 175-193.

Grupp, H., Hohmeyer, O., Kollert, R. & Legler, H. (1987) 'Technometrie', Köln: Verlag TÜV Rheinland.

Koschatzky, K., Frenkel, A., Grupp H. & Maital S. (1996) 'A Technometric Assessment of Sensor Technology in Israel vs. Europe, the United States and Japan', Int. J. Technology Management, in print.

Lancaster, K. J. (1991) 'Modern Consumer Theory', Aldershot: Edward Elgar.

Pugh, S. (1990) 'Total Design', Reading, Mass.: Addison-Wesley.

Saviotti, P. P (1985) 'An Approach to the Measurement of Technology Based on the Hedonic Price Method and Related Methods', Tech. Forecast. Soc. Change, vol. 27, 309-334.

Shillito, M. L. (1994) 'Advanced Quality Function Development: Linking Technology to Market and Company Needs', New York: Wiley.

Shoham, A., Lifshitz, S. & Maital, S. (1996) 'Technometric Benchmarking: Identifying Sources of Superior Customer Value', working paper, Technion: Faculty of Industrial Engineering & Management.

Trajtenberg, M. (1990) 'Economic Analysis of Product Innovation - The Case of CT Scanners', Cambridge, Mass.: Harvard University Press.

On Microeconomic Applications of the Solow Equation:
Partitioning Productivity Change at the
Firm Level
Theory & Illustration

Robert Solow (1965) addressed the central macroeconomic question, one that has interested economists for perhaps two centuries: Do countries become wealthy primarily through the accumulation of capital, or through accumulation of knowledge? The tool he used was the production function:

$$[1] \quad Y = F(K,L,A)$$

where Y is net output (or value added), K is capital, L is labor and A represents the level of knowledge or technology. Each of the above variables is assumed to have a time subscript "t".

Assume that technology or knowledge is independent of either capital or labor. Then [1] becomes:

$$[2] \quad Y = A\,F(K,L)$$

Assume that F( ) is homogeneous of degree one. Then:

$$[3] \quad [dY/dt] = dA/dt + (\partial F/\partial K)(dK/dt) + (\partial F/\partial L)(dL/dt)$$

Divide both sides by Y:

$$[4] \quad dY/dt)(Y) = dA/dt)(A) + (1-\alpha)k + \alpha\, l$$

where the LHS is the per cent change in value added, α is the contribution of labor to value added (wage multiplied by the marginal product of labor), $(1-\alpha)$ is the contribution of capital to value added (the return on capital multiplied by the marginal product of capital), k is the rate of growth in capital K, l is the rate of change of L. dAdt/A is the change in value added accruing to factors not related to the growth of capital K.

To compute the rate of change in value added per worker (gross labor productivity), subtract the rate of growth of L from both sides:

$$[5] \quad dY/dt/Y - l = dA/dt\,/A + (1-\alpha)(k - l)$$

In words:

the change in value added per worker is equal to:

a) the contribution of the change in technology, or knowledge, to the change in value added per worker, and

b) the change in capital per worker, multiplied by the weight of capital in value added.

In [5], all components are known, except for dA/dt/A . This is computed as a residual:

[6] $dA/dt\,/A = dY/dt/\,Y - l - (1-\alpha)(k - l)$

Solow found that a majority of nations' economic growth was attributable to the dA/dt / A factor. Controversy ensued, centering around whether it was indeed possible to separate the A( ) factor from its embodiment within labor and especially within capital.

This so-called "production function approach" (Griliches, 19??) (handbook?) has been extensively used to measure the rate of return to net investment in R&D for firm or line-of-business level data (Mansfield, 1965; Clark and Griliches, 1984; Link , 1981a, 1981b; Griliches, 1986) and industry aggregates (Terleckyj, 1974; Griliches, 1979, 1994; Griliches and Lichtenberg, 1984a, 1984b; Scherer, 1982, 1984).

In this paper, we propose using [5] and [6] as a microeconomic tool for analyzing and partitioning labor productivity change in individual firms, using publicly-available information contained mainly in balance sheets and pro-forma income statements. The result is insightful because it shows whether companies' labor productivity gains are driven principally by capital investment, or whether they are driven by "technology and knowledge

Three Illustrations:

1. Intel Ltd.

Table 1

	1994	1993	% change
	-$ billion -		
Net Revenue	$11.5	$8.8	
- Cost of Goods Sold	5.6	3.3	
= Value Added	5.9	5.5	+ 7.2 %
Labor (employees)	32,600	29,500	+10.5%
Value Added per Worker	$180,982	$186,440	- 3%
Capital (Shareholders' Equity)	$9.3 b.	$7.5 b.	+24%
Capital per Worker	$285,276	$254,237	+12%

"Solow equation":

% change in value added per worker =

"a" + (0.4) * (% change in capital per worker)

-3 % = "a" + (0.4) * (12 %)

Analysis: Intel experienced a decline in labor productivity in 1994, despite a large increase in Intel's capital, owing to "negative technological change". Closer Investigation would doubtless reveal Intel's massive shift from 486 microprocessors to the new 586 ("Pentium") microprocessor, and attendant loss of output and production time. The data indicate the costliness of such transitions, but caution investors that the productivity decline is likely temporary. Indeed, in following years, Intel's value added per worker grew impressively, driven largely by its technological change.

2. YPF Ltd.

YPF is Argentina's leading energy company. In 1991 the company was privatized, and slimmed its employment rolls down from over 50,000 employees to around 6,000 (although many of the 50,000 became private outsourcers for YPF).

YPF recorded very large gains in productivity in 1996.

Was this due to accumulation of knowledge, or capital investment?.

Solow's equation provides the answer:

Table 2.

	1996	1995	
	Billion $	Billion $	Increase
Revenues	5.9	5.0	
Cost of Sales	3.6	3.2	
Value Added VA	2.3	1.8	27.7%
Labor:no. of employees	9,700	9,300	4.3%
VA/L	237,000	194,000	22.16%
Equity (K)	6,734	5,839	15.32%
K/L	694,000	628,000	10,5%

we assume that the contribution of capital to value added is 0.4, typical for a capital-intensive firm.

Solow equation:

$$22.16\% = a + 0.4 \times 10.5\%$$

then a = 17.96%

This tells us that YPF's impressive increase in value added per worker was largely due to improvements in technology, efficiency and knowledge, rather than capital investment investment..

3. Merck Ltd.

Table 3.

	1994	1993	% change
Value Added ($ b.)	$9.0	$8.0	
Employees (L)	47,700	47,100	
Capital (Assets, K)	$21.9	$19.9	

Solow equation:

% change in value added per worker = 11.2 %

= "a" + 0.43 * (8.7 %)

"a" = 7.5 %

Merck, an R&D-intensive pharmaceutical company, showed large gains in value added per worker, primarily from increases in knowledge. Since conventional accounting does not treat R&D expenditures as part of a company's "intellectual capital", one can deduce that a significant part of Merck's productivity gain stems from its successful investment in R&D for new products.

References

Clark, K.B. and Z. Griliches. 1984. Productivity growth and R&D at the business level: results from the PIMS data base". In Z. Griliches, ed., R&D, patents and productivity. Chicago: U. of Chicago Press, 393-416.

Griliches, Z. 1986. "Productivity puzzles and R&D: another nonexplanation". Journal of Economic Perspectives. 2 (4), 9-21.

Griliches, Z. 1979. "Issues in assessing the contribution of R&D to productivity growth", The Bell Journal of Economics, 10 (1), 92-116.

Griliches, Z. 1994. "Explanations of productivity growth: Is the glass half-empty?" American Economic Review, 84(1), 1-25.

Griliches, Z. and F. Lichtenberg. 1984. "Interindustry technology flows and productivity growth: a re-examination". Review of Economics and Statistics, 66 (2), 325-29.

Link, A.N. 1981. 'Basic research and productivity increase in manufacturing: additional evidence". American Economic Review, 71, 1111-12.

Mansfield, E. 1965. "Rates of return from industrial R&D", American Economic Review, 55, 863-73.

Scherer, F., 1982. "Interindustry technology flows and productivity growth". Review of Economics and Statistics. 627-34.

Terleckyj, N. 1974. Effects of R&D on the Productivity Growth of Industries: An Exploratory Study. Washington DC: National Planning Association.

Optimal Radical Innovation

Hariolf Grupp Shlomo Maital

In Ben Arieh, Grupp and Maital (1998), we put forward new definitions of incremental, standard and radical innovation. Our taxonomy was built on the premise that products are best seen as combinations of features, or attributes – an approach developed independently, and somewhat differently, in three disciplines: economics (Lancaster, xx); management of technology and innovation (Grupp, xx; Saviotti and Metcalfe, 1984); and marketing (models' (Fishbein, 1963; Fishbein and Ajzen, 1975; Bass and Talarzyk, 1972; Wilkie and Pessemier, 1973; Curry and Menasco, 1983). We went on to construct and illustrate a mathematical-programming model for optimal incremental innovation, based on optimizing the cost-value ratios of incremental improvements in product features.

In this paper, we outline a new conceptual approach to optimizing radical innovation. While the core of radical innovation is generally, and rightly, viewed as a creative, inspirational process not easily adapted to quantitative models, we maintain that it is both possible and desirable to model radical innovation, in ways that aid decision-making and reduce risk.

Section One presents our model, and Section Two illustrates its use with several knowledge-based products.

1. A Model of Radical Innovation

Products differ, according to how they are made ("process technology"), the benefits they yield consumers (attributes), how they are used or perceived (consumer behavior), or how the product is integrated with other products or systems (architecture). Radical innovation can be defined by focusing on significant discontinuities or change in any or all of the above four aspects.

Henderson & Clark (1990) define radical innovation as fulfilling two necessary conditions: an "overturned" core concept of the product, and major change in the linkage among the core components of the product.

Mansfield (1968) and Nelson and Winter (1982) focus on the competitive consequences of radical, as opposed to incremental, innovation. Geoffrey Moore (1991) focuses on how the product is used, and defines "discontinuous innovation" as products that require us to change our current mode of behavior or to modify other products and services we rely on". (p. 10).

We choose the conventional approach and focus on product features.

We define a product, service or process as a finite collection of characteristics or attributes, all of them measurable in either physical or ordinal units (e. g. consumer satisfaction scales). For a given product, let those 'n' attributes be x_i , where i = 1, ..., n . A product, then, is simply a vector of attributes:

$$[x_1, x_2, ..., x_n]$$

Definitions:

1. An *incremental innovation* is one in which a new version of an existing product has some or all of its existing attributes improved. The new vector is:

$$[x^*_1, x^*_2, ..., x^*_n], \text{ all } x^*_i \geq x_i, \text{ some } x^*_i > x_i$$

where x^*_i is the new post-development value of attribute i.

2. A *standard innovation* is one in which the vector of product attributes is:

$$[x'_1, x'_2, ..., x'_n, x'_{n+1}], x'_i \geq x_i,$$

where x'_{n+1} represents a new product attribute that did not previously exist.

The difference between a standard innovation and an incremental innovation is that one additional attribute is added to the product, that did not exist before (while existing attributes may or may not be improved somewhat). An example could be the addition of CD-ROM read-only drive to PC's.

3. A *radical innovation* is an innovation such that 'k' significant new attributes are created, $k \geq 2$, which did not before exist - creating, essentially, a wholly new product:

$$[x^{\circ}_1, x^{\circ}_2, ..., x^{\circ}_n, x^{\circ}_{n+1}, x^{\circ}_{n+2}, x^{\circ}_{n+3}, ..., x^{\circ}_{n+k}], x^{\circ}_i \geq x_i.$$

An example is a new pen-based computer, that stores handwritten material in its memory, then recognizes each character and transfers the material to standard computer files. Some of its attributes: pen size, memory size, accuracy of letter recognition, etc., are new and are thus not comparable to existing attributes of conventional computers.

Terminology:

Pa - price of existing product "a"

Pb - price of radically-innovative product "b"

Qa - total demand for product "a" (units)

Qb - total demand for product "b"

X - (nx1) vector of n attributes for product "a"

X* - (n+k x 1) vector of n+k attributes for product "b"

FCb - total fixed (R&D) costs for developing innovative product "b"

VCa - total variable costs for producing product "a"

VCb - total variable costs for producting radically innovative product "b"

The price of each product is assumed to depend on two factors: a) product attributes, and b) other factors, such as advertising, brand name, etc.

[1] Pa = Ao + A X

[2] Pb = Bo + B X*

where A is an (nx1) vector of coefficients a1 a2... an, where ai is the subjective value of characteristic xi as reflected in the product's market price, and Ao includes all factors that influence price other than product features. Similarly, B is an (n+kx1) vector of coefficients b1 b2 b,n+k that reflect the mapping of product features into the innovative product's price.

We assume that demand for products "a" and "b" depends both on the price, and on the product's features.

[3] $Qa = f(Pa, X)$

[4] $Qb = g(Pb, X^*)$

We assume that managers seek to maximize profit. For the existing product "a", profit-maximization is formulated as:

[5] $MAX\ \Pi a = PaQa - VCa(X, Qa)$

[6] $MAX\ \Pi a = PbQb - VCb(X^*, Qb) - FCb$

The standard first-order conditions apply – e.g., equate marginal cost and marginal price. However, a new set of conditions arise, that focus on product features:

[7] $Qa\ \vartheta Pa/\vartheta xi + Pa\ \vartheta Qa/\vartheta xi = \vartheta VCa/\vartheta xi$

[8] $Qb\vartheta Pb/\vartheta x^*i + Pb\vartheta Qb/\vartheta x^*i = \vartheta VCb/\vartheta x^*I$

Equation [8] states: a radically-innovative product should be so designed, that the marginal revenue from a new product feature is equal to the marginal cost of producing that feature. This condition, of course, applies equally existing product features, and to the conventional product "a".

Finally, in order for the risk and expense of radical innovation to be worthwhile:

[9] $\Pi b \geq \Pi a + FCb\,(1+r)$,

where FCb is the fixed (R&D) costs of developing the innovative product "b", and "r" is the opportunity cost of the FCb capital, including a risk premium that reflects the degree of risk inherent in developing and marketing the radically-innovative product "b".

The model of optimal incremental innovation (Ben Arieh, Grupp and Maital, 1998) is a special case of the above model, where production technology is assumed to be linear in time, money and labor.

A key part of this model is the link between market prices P and product attributes X. ***Ex post***, this link can be explored through use of hedonic price indexes, which express market prices as linear functions of attributes and use statistical regression to estimate the coefficients; see Grupp and Maital, 1998.

But in making vital, difficult decisions about whether to embark on costly, risky R&D programs to develop radically-new products, product managers must estimate the link between P and X ex ante.

To do this, they must in some manner gain insight into consumer preferences of existing and potential buyers.

Consumers are assumed to spend their income, in order to maximize utility. Assume consumers face a wide variety of products and product attributes. For a given consumer "j" and product "a", this implies:

[10] $\partial Pa/\partial xi = \lambda \, \partial Uj/\partial xi$,

where λ is the marginal utility of one dollar. [10] states that "optimized" products are such that the marginal utility value of an improvement in a product feature equals the increase in price stemming from that improvement. In competitive markets, where producers understand buyer preferences well, this condition will evolve and ultimately hold. The same condition must hold for the innovative product 'b":

[11] $\partial Pb/\partial x^*i = \lambda \, \partial Uj/\partial x^*i$,

A "tradeoff" optimization condition can be derived from the above. Let F(x1, x2,... xn) = constant be the technology function showing the various combinations of "x" attributes that are feasible, with existing technology and resources. Profit maximization therefore implies:

[12] $[\partial F(\,)/\partial xi] / [\partial F(\,)/\partial xj] = [\partial U(\,)/\partial xi]/[\partial U(\,)/\partial xj]$, all i, j

Equation [12] states that the marginal rate of transformation among all pairs of product attributes must equal the marginal rate of substitution -- i.e., the "cost" of improving attribute "I", in terms of worsening attribute "j", must equal the marginal utility of the improvement in attribute "I", relative to the marginal utility of attribute "j".

Condition [12] is the basis of the so-called "conjoint" model in marketing, which uses choice pairs presented to buyers to estimate marginal rates of transformation, then uses additional information to simulate market shares and profitability of existing and hypothetical combinations of product features, including those for radically-innovative products, ultimately zeroing in on the optimal configuration of features.

Examples:

* RISC vs. SISC. Not all radical innovations are dominant or even profitable. Consider the Power-PC chip developed jointly by Apple, Motorola and IBM. According to Gordon Bell, architect of Digital Equipment's highly successful VAX system, "PowerPC appears to be the only architecture that can compete with the Pentium". PowerPC had strong technological advantages: smaller in size than the Pentium, lower heat generation, smaller silicon use, faster speed. Yet Pentium has triumphed in the marketplace.

PowerPC uses new reduced instruction set computing (RISC) technology. Intel at one point made a key strategic decision to dump its existing SISC (Standard Instruction Computing Set) technology embodied in the 286-386-486 microprocessors and shift to RISC technology. A small group of rebellious engineers persuaded Intel senior management to reverse course and enhance the 486, to create the Pentium. The main advantage: continuing compatibility with all existing software, while RISC technology would involve a major shift toward new software. The incrementally-innovative "compatibility" feature – tens of millions of existing PC's and software based on SISC technology – won out over the radically-innovative "faster-cooler-smaller" PowerPC RISC technology.

* electric vs. Gas combustion care

* epoxy-resin covering for pipelines, vs. Standard anti-corrosion methods...

References

* Henderson, R. and K. Clark.

* Mansfield

* Nelson, R. and S. Winter.

* Grupp, H. (1985)

* Ben Arieh, Grupp and Maital, 1998.

* Grupp and Maital, 1998.

* Moore, G. Crossing the Chasm: Marketing and Selling High-tech Products to Mainstream Customers. Harper Business: New York, 1991.

Global Integration of Marketing & R&D: IBM's Haifa Research Laboratory and its "WebCutter" technology *

Mel Horwitch[1] Hariolf Grupp [2] Shlomo Maital [3]

Galit Dopelt Galit Sobel [4]

Acknowledgements:

This case study was written by Horwitch, Grupp and Maital, based in part on research conducted by Galit Dopelt and Galit Sobel, undergraduate students in the Davidson Faculty of Industrial Engineering and Management, Technion. We are indebted to Dr. Yoelle S. Maarek, manager, information retrieval and organization group, IBM Haifa Research Lab, and the WebCutter development team; to Joshua Maor, Chairman of the Board of Directors, IBM Israel; and to Mary-Ellen Rosen and Jeff Reiser, Manager, Internet Server Architecture Group, IBM Internet Division, Raleigh, NC., for their kind cooperation. Views expressed in this case study are solely those of the authors. This case was presented at the Round Table on "New Dimensions in Global Technology Strategy: High-Tech U.S. Investment and Collaboration in Israel", Institute for Technology and Enterprise, New York, Sept. 25, 1997. We are grateful to the participants for their comments and criticism. Partial support was provided by the German-Israel Foundation grant no. I-009-118.02/94 and by the Technion Vice-President's Fund for Research.

---

[1] Chair, Dept. of Management, and Director, Institute for Technology & Enterprise, Polytechnic University, New York, NY

[2] Deputy Director, Fraunhofer-ISI, Karlsruhe, Germany

[3] Professor of Economics and Management, Davidson Faculty of Industrial Engineering and Management, Technion, Haifa Israel

[4] When this case was prepared: undergraduate students in Industrial Engineering & Management.

Summary

How can companies best integrate their marketing function with Research and Development? As product life-cycles and development cycles become ever shorter, and as increasing proportions of R&D are outsourced, linking the marketplace with the laboratory becomes both crucially important and increasingly difficult – especially for transnational companies whose R&D sites are distant from markets and marketing operations.

This case study examines integration of marketing and R&D in the context of free IBM Internet software, "Mapuccino" ™ (available at IBM's corporate Web site [5] and known internally as "WebCutter"), developed at IBM's Haifa Research Laboratory in Israel.

....

Background - the fall and rise of IBM:

"I'm amazed at how much more respect IBM has in the technology world than in the investing world."
- Daniel Mandresh, Merrill Lynch (1993) [6]

51-year-old Louis V. Gerstner, a former McKinsey & Co. consultant, took over as ceo of IBM in the spring of 1991. At the time, IBM's stock had slid to $95 from its late-1988 peak of $125.

In 1993, losses were mounting, totalling $16.6 billion in the four quarters ending 9/93, amounting to five-sixths of total shareholder equity; total return to investors was a dismal minus 15 per cent. In late 1993, IBM's stock dropped to nearly $35.

At the time the PowerPC microprocessor was the centerpiece of IBM's technology strategy. "PowerPC appears to be the only architecture that can compete with the Pentium," said Gordon Bell, architect of Digital Equipment's VAX system.[7] But despite the PowerPC's technological advantages – smaller in size, lower heat generation, smaller silicon use, faster speed – the Pentium triumphed. Intel's marketing muscle triumphed. In 1995 Gerstner disbanded the business unit that sought to build an alternative to Intel-based PC's using the Power PC chip.

Aggressive cost-cutting brought IBM back to profitability. The number of IBM employees was pared from close to 400,000 to about 250,000. By second-quarter 1995, IBM's earnings were $1.5 b. (annual rate) and its stock was back to $110.

---

[5] See: http://www.ibm.com/java/mapuccino
[6] Quoted in David Kirkpatrick, "Gerstner's new vision for IBM", Fortune, Nov. 15, 1993, p. 32.
[7] Ibid., p. 30.

In 1996 IBM's earnings were $5.4 b. on sales of $76 b., making it the 15th largest company in the world, measured by sales.[8] Its market capitalization on May 30, 1997, was $86 b., 13th largest in the world.[9]

The turnaround ceo Gerstner had engineered was impressive. But many fundamental problems remained. Perhaps the key one: IBM's lack of innovative alacrity, which kept it from translating superior technological capability into dominant market share. In comparison, Intel – IBM once owned some 30 per cent of its stock – had earnings nearly as large as IBM's, with one-fifth the number of employees and about one-fourth IBM's sales. As a result, as of May 30, 1997, Intel's market capitalization exceeded IBM's by almost one-half.

Despite its high stock price, IBM still commanded more respect in the technology world than in the investment world. For example, IBM sought to be a major Internet player. Yet new Internet-based firms' total market value soared from near-zero in April 1995 to $10 b. in April 1997, while, according to strategy expert Gary Hamel, IBM's share of total computer-industry market capitalization dipped from 46 per cent in 1988 to only 14 per cent in 1997.[10] As Hamel noted, cost-cutting and down-sizing may succeed in raising share prices, but they "do not create new wealth, do not yield new revenue streams, do not take the company into new markets, and do not create fundamentally new value for customers."

Despite Gerstner's widely-quoted – and misinterpreted - statement in the summer of 1993 that the last thing IBM needed was a grand vision, IBM does have a new value-creating strategy. That strategy is based on a network-centric model, in which IBM builds and sells networking software and hardware as an integrated systems provider. The marketplace itself helped IBM shape this strategy – IBM revenues from the sale of services grew by a third in 1995, to $12.6 billion, while other divisions stagnated or grew slowly.

Gerstner now sees IBM as a "business process outsourcer", licensing software as it once rented its mainframes.[11] IBM is arraying its global resources for an assault on the wired world. The objective: "to use [IBM's] global reach, its expertise in dozens of technologies and its knowledge of how major customers conduct their businesses to offer all sorts of computing resources across networks – either public or private ones". In a way, this strategy returns IBM to its original winning formula - leasing computer services together with superior maintenance, software and related services.

Will IBM succeed?

A major determinant will be IBM's ability to integrate its marketing and R&D functions. Ceo Gerstner stated this in a Nov. 1993 interview [See Exhibit 1].

---

[8] Fortune Global 500, Aug. 4, 1997, p. F-2.

[9] Business Week, Global 1000, July 7, 1997, p. 53.

[10] Gary Hamel, "How Killers Count", Fortune, June 23, 1997, p. 24.

[11] Business Week, Oct. 30, 1996, p. 49.

Exhibit 1

IBM as IBS (International Business Solutions): Ceo Gerstner's Vision

"Increasingly, the value for our customers is going to come in designing applications that will help them restructure their businesses. Those involve a combination of hardware, software, and services, and we've got to be able to put those together to build solutions. ....

"What we bring in our services strategy is our laboratories, right there working with customers, thinking through how technology will evolve. When the cycle of technological evolution gets more rapid, the closer you are to laboratory work, the more you will be able to give clients a solution that achieves competitive advantage. ....The issue of whose workstation or PC it is becomes less and less of an issue, as opposed to who knows how to bring about the change. ...IBM will continue to be the primary source, the dominant source, of technology in this field. I'm absolutely convinced of that because of the almost impossible task for anybody in the next five years to duplicate our R&D function. What we have got to do is convert our technology into products faster – higher-quality products that respond to our customer needs quicker. I'm driving IBM to serve our customers. What customers are telling me is stop giving me all this stuff about what might happen. Help me solve my problems."

(Fortune, Nov. 15, 1993, p. 28)

In late 1996 suggestions appeared in the press that IBM change its name to IBS - International Business Solutions. The idea was not seriously considered – perhaps because there already IS such a company, based in New York City.

The challenge to management is enormous. For instance, a far-flung global operation exists, in which IBM software programmers in China, India, Latvia, the United States and Israel write programs based on Sun Microsystems' Java language, for companies to use to create their own in-house software. The total R&D investment in this program amounts of hundreds of millions of dollars. And there are numerous others like it.

How well will IBM succeed in leveraging its technological capability to create value and rebuild its market share? IBM's Haifa (Israel) Research Laboratory is one of only three such IBM laboratories outside the United States. Its history and evolution are instructive in examining IBM's technology-marketing interface. Before analyzing its WebCutter product, we first review HRL's history.

IBM (Israel) and the Haifa Research Lab (HRL):

> "What we bring in our services strategy is our laboratories, right there working with customers, thinking through how technology will evolve."
> Lou Gerstner, 1993[12]

IBM established its Israeli branch in 1949, just one year after the country was born. IBM's Scientific Center (now Haifa Research Laboratory) was established In Haifa in 1972, and was founded and headed by Dr. Josef Raviv, a leading IBM scientist. Raviv chose at that time to return to his home country, Israel, from the United States, and corporate IBM recognized his value to the company in part by providing resources for him to build a scientific center there.

Sweeping changes have occurred in the focus, character and organizational structure of HRL, changes that are reflective of IBM's new directions and its approach to integrating marketing and R&D. Many of those changes were implemented or guided by IBM Israel's current chairperson, and previous managing director, Joshua Maor.

Maor, trained as an electrical engineer, worked for a decade with the Israel Defense Force's computer installation, becoming deputy director. He developed expertise in software, a new field at that time, through the need to develop diagnostic tools for hardware. Maor then joined IBM Israel's marketing department, working with universities and research institutions in Israel. In the mid- 1970's, he was transferred to IBM's European division headquarters in Paris, where he was part of a team that sought solutions to the division's growing business problems. Maor notes that his stint in Paris helped him understand the links between "corporate" IBM and branches in individual countries.

---

[12] Fortune, Nov. 15, 1993, p. 28.

In 1980 Maor returned to IBM - Israel as head of marketing, and became managing director in 1984. Shortly after, in July 1985, the Israeli government implemented a sweeping plan to halt the runaway inflation that afflicted the country. The result was a serious, prolonged economic slowdown. IBM Israel, structured for 18-20 per cent annual growth in sales, was forced to restructure and refocus its business strategy. [This occurred somewhat before IBM Worldwide underwent a similar, wrenching process, revising its near-term sales projections sharply downward from the $100 b. level.] At the same time, PC's, accounting for about a quarter of IBM Israel's business, were becoming a commodity-like product with sharp downward pressure on prices from IBM-clones.

"We had the high cost levels of 1976," Maor noted, "and the lower growth rates of 1986. The two were inconsistent. We decided to cut costs, and at the same time shift our focus toward the service part of our business. During the period when we focused on hardware sales, we lost some of our capability as solutions providers, while other such providers in Israel grew stronger. So at the same time, we had to slash expenses while building up the systems part of IBM Israel."

The key to this strategy -- which preceded a similar strategic shift in IBM's global operations - was, according to Maor, IBM's Scientific Center in Haifa. The Center's objectives, and its very name, were radically changed. Until then, a typical IBM Scientific Center engaged in research together with other research bodies, to contribute to scientific knowledge and to the community.

"We changed its name to the Science and Technology Division," Maor recalls. "Two major changes followed. First, the division began to do more contract development work for corporate IBM in the U.S. Second, we created an Advanced Solutions Center unit in Haifa whose mandate was not only to develop new technologies, but to build business solutions based on those technologies."

> As an example, Maor cites a new system announced in late 1996, developed in Haifa, in which X-ray, MRI and other medical images are digitalized, stored, analyzed and transmitted to distant sites to facilitate medical diagnosis and treatment in a cost-effective manner. The system is based on sophisticated integration of software and hardware and is now in place in Israel and several European sites. It took eight years to perfect.

In the late 1980's, IBM branches in other countries experienced the same growth slowdown that IBM Israel encountered in 1985. IBM Israel, having had the "good fortune" to grapple with the local downturn, unrelated to global industry or IBM problems, was as a result better prepared for the slowdown than IBM branches in other countries.

In Israel and elsewhere, IBM shifted its focus from research to development. IBM scientific centers, where once scholars pursued research independently, based on their own interests, not unlike academic departments, became much more focused and directed. IBM's Scientific Center in Haifa, as the core of IBM Israel's Science & Technology Branch, grew from 20-30 researchers to over 350 employees. Hiring policies increasingly sought talented engineers and scientists with market-based interests.

As Managing Director, Maor personally sought out scientists at the Haifa lab who were keenly interested in seeing their ideas applied in the marketplace, rather than simply published in academic journals. The profile of researchers at the Scientific Center greatly changed. This process of change was neither simple nor easy nor rapid, and was one that many IBM research installations in other countries underwent.

The basic management change was to separate the research and the development functions. IBM continues to engage in research, but is more strongly focused on development. At IBM Israel, this shift occurred as much as a decade earlier than it was implemented throughout the global IBM operation.

> In Jan. 1997, a major organizational change occurred. HRL was transferred from IBM (Israel) to IBM's worldwide R&D organization. While administration of HRL is still done by IBM Israel, HRL now actively seeks internal customers and projects in other IBM branches and divisions.

Integrating Marketing & R&D at IBM: Developing "WebCutter"

The Technology: "WebCutter" is a Java-based Internet tool that builds and maintains visual maps for Internet sites.[13] It does not utilize search engines at all, but rather uses its own built-in dynamic search instead of the slow static search services. IBM regards WebCutter not as a "product" but rather as a tool/system/solution/service. It is fully compatible with all Java-enabled browsers. It forms part of an overall strategic initiative to develop a broad range of Java products for Internet servers. WebCutter's development began at IBM's Haifa Research Laboratory in June 1996; the WebCutter technology was announced in June 1997. It is available as freeware at IBM's corporate Web site, and is known there as Mapuccino (trademark).

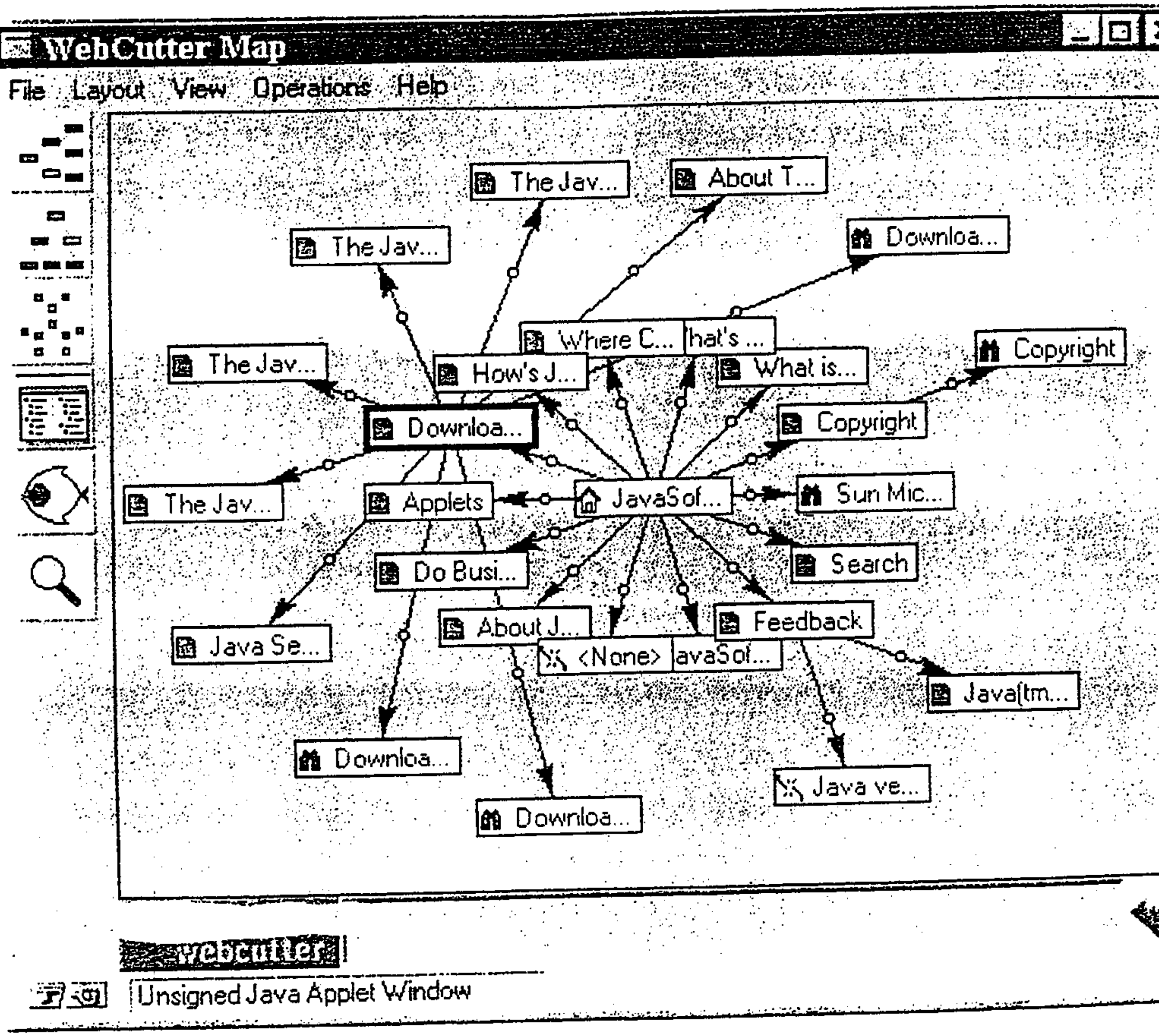
> WebCutter provides a detailed, organized visual "street map" of Internet sites, capable of leading users quickly and efficiently to their desired destination. It offers several different types of maps, including: a "starshaped" map, showing various parts of the site and how they are linked. [See Exhibit 2]. b) a "fish-eye" map, which magnifies those parts of the site relevant to the user, and minimizes other parts less relevant.

---

13 See: Y. Maarek, M. Jacovi, M. Shtalhaim, S. Ur, D. Zernik and I. Ben Shaul. "WebCutter: a system for dynamic and tailorable site mapping". Journal of Computer Networks and ISDN Systems, 29, 1997, pp. 1269-1279. An earlier version appeared in the Proceedings of the WWW6, Santa Clara, CA., April 1997.

Exhibit 2. Webcutter Map
of Sun Microsystem's Java Internet site

35x452 pixels



WebCutter uses IBM's proprietary "conceptual search" text-analysis technology. Users indicate their interests in plain language, and WebCutter maps relevant sites in ways adapted to, and meaningful for, users. Color coding directs the eye of the user to important areas in the site. WebCutter is capable of integrating several sites into a single map. It is compatible with all browsers now in use, and can be used on both Unix and NT servers.

The Market: Who are the potential customers/users for WebCutter? There are two separate markets, which differ considerably:

a) Websurfers - those who surf the Internet, seeking information, and

b) Webmasters - those who build Internet sites.

Surfers' needs and wants differ greatly from Webmasters (site managers). The latter use WebCutter to optimize design of sites, and increase their clarity and attractiveness to users. Surfers use WebCutter to facilitate browsing. While Webmasters are likely willing to pay significant sums for tools that improve their capabilities, surfers for the most part are accustomed to acquiring Internet software without charge.

Competing Products: WebCutter has competition: Microsoft's NetCarta webmapper; MAPA; and NetScope. (NetCarta was an Internet acquisition of Microsoft).

Five key technological features of the four competing products were identified:

◊ Display - quality and variety of display options

◊ Achieves its objectives - degree to which product maps site information

◊ User-friendliness and documentation - degree of assistance available to users

◊ Usefulness - availability of statistical information (e.g. number of 'hits'), integration of several sites, use of filters, search options, etc.

◊ Performance and stability - time it takes to construct a visual map, compatibility with internet protocols.

These features were aggregated from 15 individual product features.

Exhibit 3 compares the key features of the four products, quantifying each on a scale of 0 to 3.

Exhibit 3. Comparison of Webcutter with Competing Products*

* Features are scored on a scale of one to three by a panel of potential users. Weight reflects the relative importance of each feature, as stated by the user panel. Simple average is the average of the five feature scores; weighted average is the feature score weighted by the feature's relative importance.

Feature	Weight	Webcutter	NetCarta	MAPA	NetScope
Display	3	2	3	1	3
Achieves Obj.	2.5	3	3	1	3
User-friendly	2	3	2	1	2
Usefulness	1	2.5	2	1	1.5
Perform.	1	1.5	2	1	1
Average	-	2.4	2.4	1	2.1
Wtd. Av.	-	**2.47**	**2.58**	**1**	**2.42**

We assembled a panel of four potential WebCutter users, including a Website developer, a Website manager, and two Internet users. It was not our intention, of course, to conduct serious market research. The objective was to elicit perceptions of the product on the part of a small number of knowledgeable users, and match those perceptions against the beliefs of the developers. We sought to show that even a small sample of users could generate useful, important information for developers.

We asked them to rate the importance of each of the five product features on a scale of one to three. The average scores are shown in Column 2 of Exhibit 3. We discovered from conversations with our panel, that the quality of the display was the most important feature, both for browsers and for Website developers and managers.

Clearly, WebCutter's main competitor is Microsoft's NetCarta. NetCarta's display scores higher, according to our panel; this is the principal reason that the weighted average score of WebCutter's features falls slightly below that of NetCarta.

How closely did the market perceptions of WebCutter's developers match those of the market itself? To check this, we asked the developers to rate the importance of the five product features, and compared the results to the ratings of our user panel. (See Exhibit 4).

Exhibit 4. Importance of the Five Product Features: Perceptions of Developers vs. Users

Feature	Developers	Users
Display	2.5	3
Achieves its objectives	3	2.5
User-friendliness	1.5	2
Usefulness	2	1
Performance and stability	1	1

Developers rated usefulness, and "achieving its objectives" more highly than users, but rated display and user-friendliness less highly. This is not atypical of product development, where the technical skills of developers are highly refined and often lead product developers to misperceive the crucial importance of making products simple, clear, friendly and easy to view, for users whose computer skills are often minimal.

Psychology vs. Technology: A key measure of how well marketing and R&D functions are integrated is this: **How well do product features (technology) match market preferences (psychology)?** In general, where marketing inputs have significant voice in R&D decisions, product features will reflect buyer preferences strongly.

To examine this in the context of WebCutter, we applied a model developed in Grupp & Maital (1997) and Ben Arieh, Grupp & Maital (1998).[14] This model plots the scores of product features against the weights or importance of those features.

Four types of products are identified:

a) Focused products: where highly-valued product features are also those in which the product scores high, and low-valued features are those where the product scores low

b) Unfocused products: where highly-valued product features are precisely those in which the product scores low

c) Dominant products: where all product features score high, including those not highly valued by customers

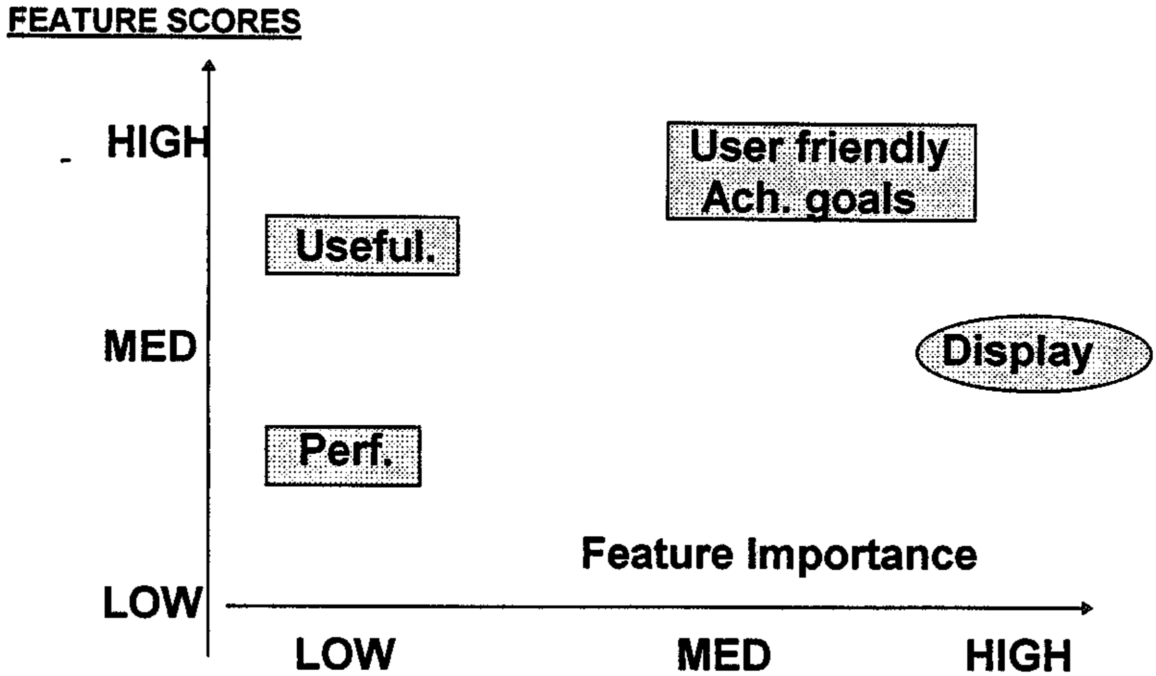
d) Inferior products: where all product features score low, relative to competitors.

Exhibit 5 shows this diagram for the WebCutter.

While WebCutter appears reasonably "focused", it was in our view significant that it fell somewhat short of competitors in a key feature – display – valued highly by the market.

[14] Hariolf Grupp and Shlomo Maital. "Identifying Sources of Value a Capital Goods Market: The Case of Industrial Sensors". R&D Management, 1997; and Ben-Arieh, Grupp and Maital, "Optimal Incremental Innovation: Integrating Marketing & R&D", Research Evaluation, forthcoming, 1998.

Exhibit 5. WebCutter: Psychology vs. Technology



It was significant, in our view, that the exceptionally talented, creative developers at HRL did not have significant, ongoing direct contact with users or the marketplace. We felt that the distribution of WebCutter to beta-sites, for instance, was not optimally exploited to bring significant information, feedback or benefit to product developers.

Based on our interactions with potential users, and the above analysis, a number of suggestions were made to the developers, several of which were accepted and implemented.

Integrating Marketing & R&D with IBM's WebCutter:

Exhibit 6 diagrams the organizational structure linking marketing and development for WebCutter.

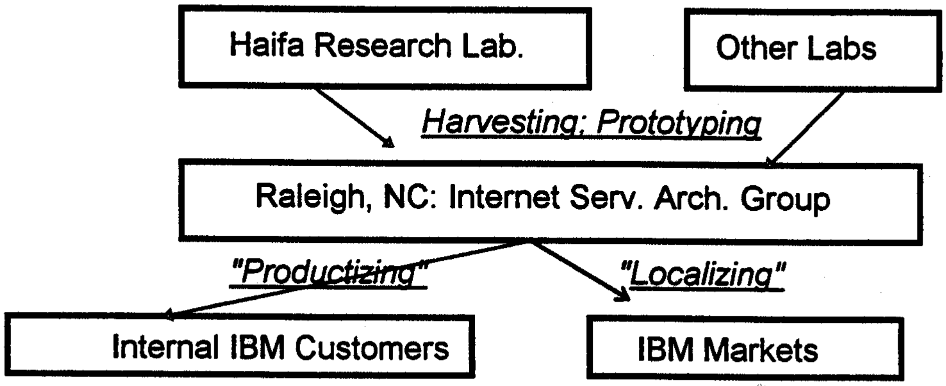
A variety of Internet products are currently under development by IBM's Internet Division. A large set of Java-based applications is currently in process. The Internet Server Architecture Group, based in Raleigh, NC, spearheads applications, prototyping, product development and business planning. This group monitors relevant research carried out at IBM's labs and research centers. Members of the group spend time at these various labs, in order to "get in synch with them".

The general pattern is one of:

Prototyping to Productizing to Localizing

that is – developing prototypes of products based on research and development, then turning prototypes into products, then adapting those products to local market needs.

Exhibit 6. Integration of Marketing & R&D
in IBM's Internet Server Architecture Group



Part of the group's mission involves product benchmarking. Its expertise, according to key members, is in "harvesting" the research developed in IBM labs (like that in Haifa) and in building prototypes.

The group's mandate is to "look around the corporation" and "to play a coordinating role". The general development pattern is for the group to discern market-based requirements for a product, and then develop and deliver products that meet those requirements.

Strategic Issues:

1. Is IBM's current organizational structure – specifically, the links among its research labs (including HRL) and marketing and business planning units in the United States - capable of optimally and rapidly translating the needs and wants of both internal IBM units and external IBM customers into winning innovative products? How might it be modified?

2. Is the process whereby new product ideas are "harvested" from IBM's R&D units worldwide conducted optimally? What measures could improve this process?

3. Is the new organizational structure, through which HRL reports directly to IBM U.S., preferable to one in which HRL is an integral part of IBM Israel? How does that change impact the integration of marketing and R&D at HRL?

4. What does the WebCutter case indicate regarding IBM's ability to speed up its product development process, and better exploit its high-level scientific and technological capabilities?

5. What can be learned from WebCutter, regarding IBM's ability to engage in "concurrent engineering" – the simultaneous development, prototyping, production and marketing of new products?

6. How could key market-based information better be brought to HRL developers?

7. IBM has chosen to provide Mapuccino TM as freeware, through its Internet site. Were there other marketing options? Was this the correct one? How could other options be explored?

Conclusion:

Hasso Plattner, founder and vice-chairman of SAP, a global leader in business-application softwaré, once said:

> I'm not interested in whether in whether we are better than the competition. The real test is, will most buyers still seek out our products even if we don't market them.[15]

In other words: by far the most effective marketing tool is from the outset to develop products so desirable in the marketplace that marketing becomes almost unnecessary. While this may seem to be a farfetched ideal for most companies, it is in fact achieved by high-growth innovative companies. Only by effectively, seamlessly integrating the knowledge and experience of a company's marketing function - market psychology - with the capabilities and creativity of the developers and researchers – technology – can this ideal be attained.

As the case of WebCutter indicates, integrating marketing and R&D remains one of senior management's most difficult and challenging tasks.

Postscript:

After this case was completed, Microsoft announced it was changing the focus of its NetCarta product from "end-user site mapping" (i.e., for use by Web browsers) to part of its site management tools. Its new product name: Site Analyst.

[15] Cited in: W. Chan Kim and Renee Mauborgne, "Value innovation: The strategic logic of high growth". Harvard Business Review, Jan-Feb. 1997, p. 106.

References & Further Reading

Maarek, Y., M. Jacovi, M. Shtalhaim, S. Ur, D. Zernik and I. Ben Shaul. "WebCutter: a system for dynamic and tailorable site mapping". Journal of Computer Networks and ISDN Systems, 29, 1997, pp. 1269-1279. An earlier version appeared in the Proceedings of the WWW6, Santa Clara, CA., April 1997.

MacMillan, Ian, and Rita G. McGrath. "Discover your product's hidden potential". Harvard Business Review, May-June 1996.

Ulrich, K.T. and S.d. Eppinger. Product Design & Development. McGraw-Hill: New York, 1995.

"Making the Cut". IBM Research, no. 4, 1996.

Java World. JARS applet reviews.

Partitioning Market Value Between Product Attributes and Brand Name: A Data Envelopment Approach

Amnon Frenkel
S. Neaman Institute
Technion

Hariolf Grupp
Fraunhofer-ISI

Shlomo Maital
S. Neaman Institute
Technion

Abstract

In Lancaster's (1981) consumer theory, buyers choose products according to how well product attributes suit their utility functions, while producers design product features to match market demand. Product price reflects value created by products, through a) its objective features, and b) its brand name, signifying quality, service, etc.

Grupp's technometric benchmarking model (1986) has shown how to quantify and compare product attributes, in an objective manner.

In this paper, we use a variation of linear programming, known as data envelopment analysis (DEA), to estimate the efficient frontier of product attributes. For products falling inside the frontier, we infer the value created by brand name effects as the proportional distance to the frontier. Our model yields a quantitative estimate of the contribution to price of "brand name".

We illustrate our model with a study of the market price of industrial sensors.