Journal of Universal Computer Science, vol. 8, no. 5 (2002), 516-525
submitted: 4/2/02, accepted: 3/5/02, appeared: 28/5/02 © J.UCS

Bibliometric Analysis and Visualisation of Intellectual Capital

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Abstract: On the basis of an example gained from the perspective of a person reading Intellectual Capital (IC) reports this paper explains the method of BibTechMon^{TM} which is based on an analysis of the co-occurrence of different terms within databases and the algorithm to visualise the results [Kopcsa, A., Schiebel, E. (1998b)]. The application of this method for the IC report is currently a major step in improving the IC reporting system within ARC Seibersdorf research GmbH. In this paper the advantages and potentials of using BibTechMon^{TM} in the context of IC reporting will be demonstrated by means of the 2001 IC report of ARC Seibersdorf research GmbH.

Key Words: Intellectual Capital Report, Relational Capital, Knowledge Map, Network
Categories: H.3.1, H.3.3, I.2.4

1 Introduction

In recent years there has been a noticeable change in business as companies have been increasingly investing in knowledge-based resources. This is expressed by businesses investing less in physical goods such as capital investments, machines, materials, energy etc. and increasingly in soft factors such as human resources, research and development, organisational development, software, marketing and relationships. This change is proof of the ever growing phenomenon referred to as the knowledge-based economy [OECD (1999)]. The investment in such soft factors is referred to as investment in intangible assets, the resources and assets generated by these investments are often called intellectual capital [Steward (1997)]. All organisations within the economy, especially those that highly invest in knowledge-based resources (e.g. research firms, high-tech firms, human capital-intensive firms) are faced with the task of using knowledge based resources efficiently, auditing the investments, managing the changing production process, establishing the results and reporting the facts to the different kind of stakeholders.

In the context of this transformation, traditional management and reporting systems lose their relevance because they are unable to provide the management and investors with information essential for managing knowledge-based processes and intangible resources. Especially the accounting system has always been focused on physical and financial assets and transactions and has so far not been able to trace the

intangible transactions within the firm. Furthermore, the traditional accounting system doesn't deliver information for investment decisions and the strategic management of the knowledge based resources.

One promising and currently intensive discussed instrument to overcome the weakness of traditional accounting and management instruments is the development of a new management and reporting system in form of an Intellectual Capital Report (IC Report). Different organisations, especially in the Scandinavian region, started to develop IC Reports to measure intellectual capital of firms and communicate the results to different stakeholders. The first European research organisation which published an IC Report is ARC Seibersdorf research GmbH (Seibersdorf Research), which published its first IC Report for the business year 1999. On the basis of the provided information a better valuation and management of knowledge-based resources of a firm should be possible.

2 Intellectual Capital Reports

2.1 Methods for Measuring and Reporting Intellectual Capital

In the last years various approaches for measuring intellectual capital have been developed in theory and practice [see for instance Sveiby (1997) and Edvinsson and Malone (1997)]. The majority of these approaches records intellectual capital with the help of financial and non-financial indicators. Hereby different forms of intellectual capital are differentiated and each asset is valued with the help of indicators. With the aid of indicators strategically relevant, intangible factors are measured (for instance the length of product development, customer satisfaction, etc.). The approaches are all similar in structure: Based on a model differentiating between the various forms of intellectual capital, each form is evaluated and subjected to descriptive interpretation, which, in turn, is based on indicators.

Various approaches already succeed in grasping the complexity of the valuation of intellectual capital and knowledge-based process but also meet with certain limitations. The approaches have different kinds of restrictions and only partly fulfil their expectations, as recent empirical and theoretical studies demonstrate [Caddy (2001), Bornemann and Leitner (2001), Fröhlich, D., Noll, M., Schiebel, E. (2001a)]. The problem of the relation between inputs and outputs and the issue of tracing flows between different kinds of intellectual capital are important deficiencies of these approaches. Also there still exists no standard for the development of IC Reports and definition of indicators, which does not facilitate the interpretation of the published data.

One critical issue for improving IC Reporting systems is the task how to interpret the new generated information. Very often the indicators published in IC Reports are highly aggregated and thus cannot serve the real information needs of the addressed internal stakeholders, especially the management. An instrument which could help to interpret and analyse these indicators in more detail would therefore be an innovative step towards increasing the significance of information published by IC Reports. When interpreting indicators of an IC Report and analysing them in more detail it is necessary to enable the reader to get more information about the composition on these

indicators and to give an example. He might also be interested in carrying out different kinds of comparisons and benchmarking on different levels, for instance between organisational units, employees, projects, etc. Usually therefore he needs a very huge amount of data which has to be structured before any useful interpretation is possible by the reader. For such an efficient structuring of information a bibliometric method [Kopcsa, A., Schiebel, E. (1998b)] can be used which allows the analysis of information on an electronic basis which will be described in chapter 3.

2.2 The IC Report of ARC Seibersdorf research GmbH

Seibersdorf research is the biggest Research Technology Organisation (RTO) in Austria with public and private owners and run as a private limited company. The main task of Seibersdorf Research is to perform a transfer function between the basic research at universities and the applied research and development in companies. Currently Seibersdorf Research is engaged in the fields of information technology, material technologies, life sciences, engineering, nuclear safety and systems research. About 400 employees work on public-funded research projects and industry-funded applied research and development projects.

For RTOs a challenge is to evaluate and communicate research and business activities as well as performance to their stakeholders. Research is not self-explanatory, its benefits must be interpreted and communicated in a comprehensible way. In the mid nineties Seibersdorf Research realigned its strategy in order to become a knowledge company and therefore started to improve the transparency of its intangible assets.

The ARC IC Model (see fig. 1) was designed to trace the knowledge production processes and knowledge flows of a research organisation and integrates the classification of intellectual capital (see Ohler & Leitner, 1999; Schneider, 1999).

In the following the inherent logic of the model is briefly explained: The process of acquiring, applying and exploiting knowledge starts with the definition of specific knowledge goals, which are derived from the corporate strategy. Knowledge goals define the knowledge base where specific skills, structures, relationships should be leveraged or built up to support the execution of the corporate strategy. These goals form the framework for the utilisation of the intellectual capital at Seibersdorf Research, which is composed of structural, human and relational capital (see Stewart 1997, Edvinson and Malone, 1997 or Sveiby 1997). These intangible resources are the input for the knowledge utilisation and production process, which, in turn, is manifested in several projects.

Depending on a specific project assignment, either all three elements of intellectual capital are utilised equally or some elements are applied selectively. There are numerous interactions and knowledge spill-over effects in the process.

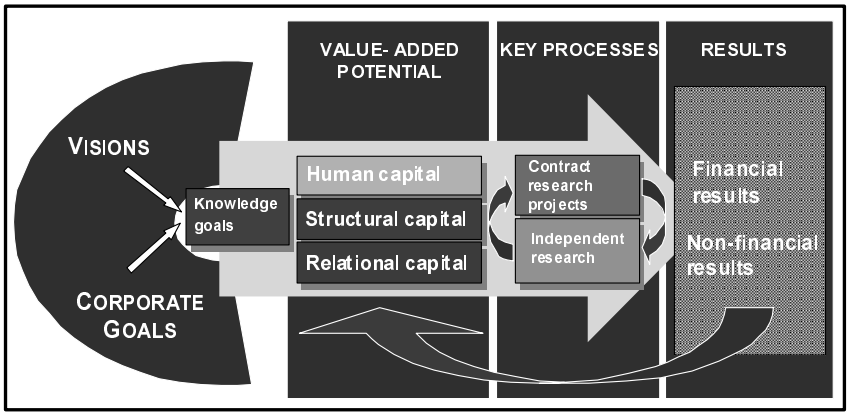

Fig. 1: ARC-IC-Model © Austrian Research Centers, 2000

The project output can be differentiated in several categories of results. Financial profit alone has limited value as a measure of the success. The model therefore identifies non-financial results which are classified as economy-oriented, research-oriented or society-oriented. Results are generally difficult to express in financial numbers and might have a financial impact only later in time. However, they might as well have various other impacts for the economy and society in general.

This Model is the conceptual framework for the IC Report, which is "activated" through a set of indicators and their interpretation. In the following section the experiences with the implementation process are illustrated by contrasting some of the most challenging dichotomies between different requirements of an IC report as well as compared to financial reporting.

On the basis of this model the first IC Report of Seibersdorf Research was implemented in a six-month lasting process started at the end of 1999. The main tasks during the implementation process were to define indicators, gather data and prepare the IC Report. The interpretation of indicators is the integral task when preparing the report. The Seibersdorf Research IC Model is the conceptual framework for the IC Report, the model is thus "activated" through the interpreted indicators. Nearly all data has been interpreted and, if possible compared with other benchmarks or with the corporate aims.

The first IC Report was finally published in May 2000 as a supplement to the Annual Report for the reporting year 1999 (See also www.arcs.ac.at/publik/fulltext/wissensbilanz). Afterwards a communication process within the whole company and various stakeholders started.

Since the first two IC Report of Seibersdorf Research were developed for the whole company the indicators for the different departments have been aggregated. Therefore the specifics of the individual departments were not considered. Thus, for the internal communication, a separate or individual analysis was implemented in 2001 in order to enlarge the IC Report as an internal management tool. For this task BibTechMon^{TM} was used, which is described in the next chapter.

3 BibTechMon™ Method

A special software called BibTechMon™ which was developed at the department of Technology Management of Seibersdorf Research can be used to perform a structuring and visualisation of several thousands of electronic documents based on their contents [Kopcsa, A., Schiebel, E. (1995c)].

When using BibTechMon™ for relevant documents of a firm the user is enabled to learn about relations, tendencies, irregularities and developments inside the company. Therefore the developed process represents a mighty planning and control instrument which helps managers to understand what's going on inside their firm within certain areas, departments or projects and also to see the collaboration between those.

3.1 General Description of BibTechMon™

BibTechMon™ is based on a bibliometric method for structuring information using co-word analysis [Kopcsa, A., Schiebel, E. (1998b)]. It is based on the calculation of co-occurencies of words which means the common occurrence of words or groups of words in documents. The more often co-words are commonly mentioned in documents the stronger is the relation between them and the common context in which they occur. Using the Jaccard Index the software calculates the intensities of all existing relations between co-words. For an easy interpretation of the derived relations these are shown in form of geographical information in a so-called "knowledge map".

Besides this visualisation of contents-based relations BibTechMon™ makes easy any further analysis of the observed words, their relations, the contents of the whole documents and the topics they are dealing with. As an example for such an analysis all publications of Seibersdorf Research in 2001 were observed, which is described in the next chapter.

3.2 Networks of Departments of ARC Seibersdorf research GmbH

Within the Seibersdorf Research IC Report the number of publications per scientific employee is published. As mentioned based on a BibTechMon™ analysis a lot of additional valuable information, such as publication activity of certain departments or authors as well as co-operation of individual authors, departments or the entire enterprise can be retrieved from the database of publications. In addition, the "knowledge map" generated by BibTechMon™ makes obvious relations between departments of authors and simplifies any further analysis.

In the following example the database of publications of Seibersdorf Research in the year 2001 was analysed by the means of BibTechMon™. As a basis for the co-word analysis authors of articles in the database were chosen as co-words, which means that authors who commonly published an article are co-authors and therefore have a certain relation. The intensity of their relation depends on how many articles they published together. However we were not interested in the publication and

networking activities of every single person but we preferred a higher granularity. Therefore we substituted each author by her or his affiliation which is a Seibersdorf Research department or a foreign partner institute. Hence relations between departments are based on common publications of their employees.

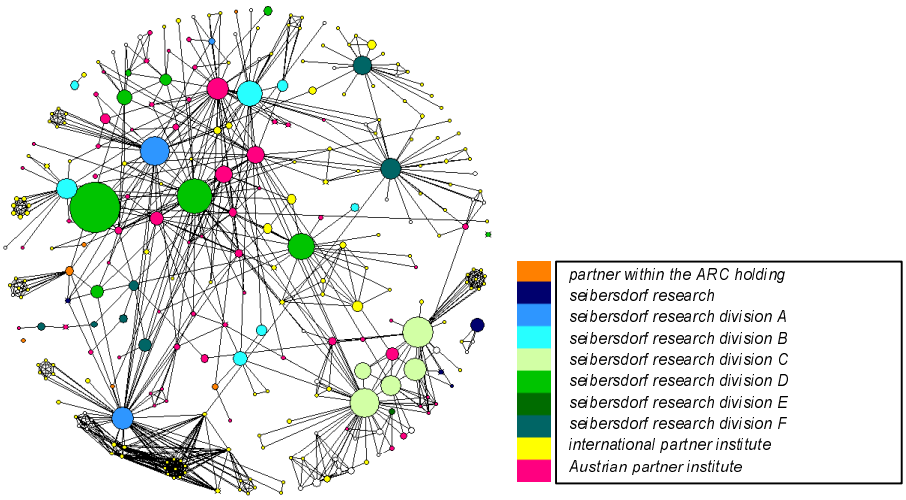

Figure 2: Co-operation network of departments of Seibersdorf Research and their partners based on publications in the year 2001.

The bibliometric method of the software BibTechMon™ then calculated a network of departments based on these publications (see fig. 2). The circles represent departments of Seibersdorf Research and their international and national scientific partners as well as those within the ARC holding. Circle size corresponds to the number of publications of the departments it represents. The position of the circles and their connections show how intensively each department co-operates with each other. For easier interpretation we marked all departments of a certain Seibersdorf Research division in a certain blue or green tone, national partner institutes in pink, international partners in yellow and sister organisations (within the ARC holding) in orange colour. From the structure of the image we learn about quantity and quality of co-operations between departments within the company and with their extern partners.

For instance the blue circle in the lower left part of fig. 3 (black arrow) represents a department (department A) with a lot of collaborations with various international partners. This department seems to be very internationally oriented and is therefore positioned nearer to the edge of the map than to its centre because the high number of extern partners (who do not collaborate with anyone else in the firm) drag it out of the centre of the map.

However the position of the big green circle in the upper centre of the picture (white arrow, department B) indicates a central role. Therefore this department seems

to collaborate intensively within Seibersdorf Research and with partners who themselves are very integrated in the network.

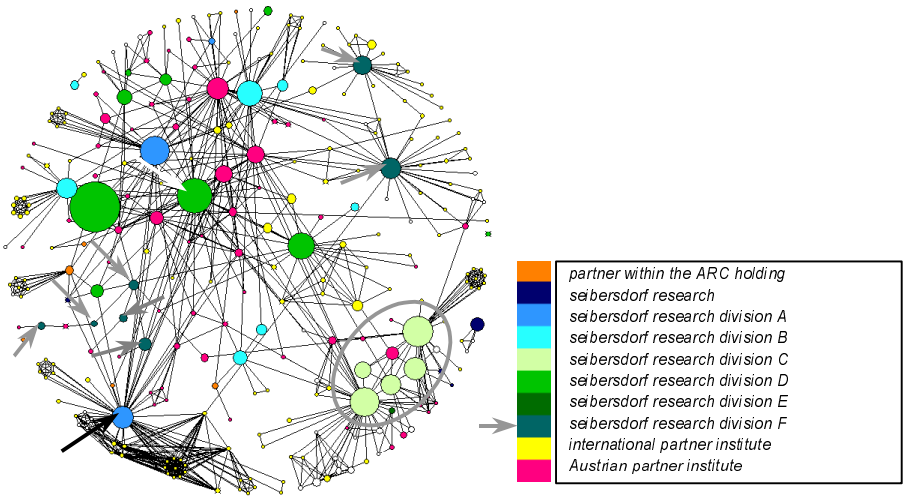

Figure 3: Co-operation network of departments of Seibersdorf Research and their partners based on publications in the year 2001. Black, white and grey arrows and ellipse mark departments or divisions, respectively, referred to in the text.

We tried to prove this obvious interpretation by the definition of useful indicators. For both mentioned departments we retrieved the number of co-operations (which means publications) with international (n_i), national (n_n) and internal partners (n_{sr}) and divided them by the total number of co-operations (n_t). Our results indicate the intensities of scientific collaboration with intern (i_{sr}), extern but Austrian (i_n) or international (i_i) partners of the regarded department (see table 1).

These indicators seem to be useful to prove our previous suggestions:

mainly internationally orientated department → i_i *= 63%*

department with mainly Seibersdorf Research partners → i_{sr} *= 50% and other well linked partners* → i_n *= 36,5% (Austrian institutes play very central roles within the network, which we can see in fig. 2.)*

Department A	**Department B**
$n_t = 76$	$n_t = 252$
$n_i = 48 \rightarrow$ **i_i = 63%**	$n_i = 34 \rightarrow$ **i_i = 13,5%**
$n_n = 14 \rightarrow i_n = 18{,}5\%$	$n_n = 92 \rightarrow i_n = 36{,}5\%$
$n_{sr} = 14 \rightarrow i_{sr} = 18{,}5\%$	$n_{sr} = 126 \rightarrow i_{sr} = 50\%$

Table 1: Indicators of the intensities of collaboration with intern (i_i), extern Austrian (i_n) and extern international partners.

Through the colour code of the circles some interpretations on co-operations of and within divisions become obvious and some need further examination. For example the light green circles in the lower right region of the image (grey ellipse) which all belong to division C are assembled very close to each other building a cluster. Hence the co-operations within this division must be much stronger than those with other divisions and most of their partners.

The departments building the division F (grey arrows), however, are spread over the whole map. Co-operations with partners outside the division seem therefore to be as intensive as those within the division.

Again we tried to prove this suggestion by a set of indicators describing the intensities of internal or external linkage of divisions (based on common publications). For both mentioned divisions we derived the number of co-operations (which are common publications, n) and pairs of co-departments (which are departments with common publications, p) within the division (n_{int} and p_{int}) as well as with partners outside the division (n_{ext} and p_{ext}). By division of n by p we calculated linkage intensities l_{int} and l_{ext}.

As we can see from table 2 the number of common publications with partners from outside the division C is even higher (n_{ext} = 185) than those within the division (n_{int} = 132). However, these internal co-operations are established by a few partners only and their connectivity is therefore rather high (l_{int} = 13,2) compared to the one of division F (l_{int} = 2,7). The division C had as many as 185 co-operations with outside but with a lot of different partners, which causes a *5,7 times lower external linkage intensity* (l_{ext} = 2,3) than internal one.

The internal linkage intensity of the division F (l_{int} = 2,7) (which is significantly lower than the one of division S) and an external linkage intensity l_{ext} = 1,6 cause an only *1,7 times lower external linkage intensity* than internal one.

Division C	Division F
$n_{int} = 132$, $p_{int} = 10$ → **$l_{int} = n_{int}/p_{int} = 13,2$**	$n_{int} = 8$, $p_{int} = 3$ → **$l_{int} = n_{int}/p_{int} = 2,7$**
$n_{ext} = 185$, $p_{ext} = 80$ → **$l_{ext} = n_{ext}/p_{ext} = 2,3$**	$n_{ext} = 90$, $p_{ext} = 58$ → **$l_{ext} = n_{ext}/p_{ext} = 1,6$**
→ $l_{int} = 5,7 \cdot l_{ext}$	**→ $l_{int} = 1,7 \cdot l_{ext}$**

Table 2: Indicators of the intensities of internal and external linkage of divisions (based on common publications).

Again the defined indicators seem to be useful to prove our suggestions:

stronger co-operations within division C than with outside → $l_{int} = 5,7 \cdot l_{ext}$

nearly as intensive co-operations with partners outside the division → $l_{int} = 1,7 \cdot l_{ext}$

3.3 Interpretation of the Example within the Context of the IC Report

As mentioned in chapter 2 relational capital is one important form of intellectual capital within the Seibersdorf Research IC report. In 2001 several indicators were used to describe this capital form, as for the category "Diffusion and Networking per Scientific Employee" for example the "Number of Attended Conferences" or the "Number of Conference Talks" were used and for the scientific results, for instance, the "Number of Publications".

Of course, to use these indicators for the description of the relational capital which is a network of co-operations will never be as complete as a representation of the whole network with all its interactions. However, measuring all kinds of relations inside a firm and with outside would mean considering any kind of communication of employees between each others and with extern people and is therefore hardly or not to fulfil. But what can be done is evaluating all kinds of relations of a firm which have certain measurable results such as projects, meetings, publications etc. provided that this data is stored in a sufficient way.

In the case of the Seibersdorf Research IC report 2001 all kinds of scientific relations which resulted in publications were analysed. In addition to the number of publications the relations behind these publications, which means who published together with whom how often and on which topics were observed. This network of internal and external relations of departments and/or divisions can be very efficiently illustrated by a picture. Fig. 2 which was described in the previous chapter was calculated as such a representation of this scientific network. It explicitly shows the scientific part of the "relational capital" of Seibersdorf Research. And as we showed in the previous chapter from the BibTchMon^{TM} picture we can easily make a lot of important qualitative interpretations on the scientific relations of Seibersdorf

Research. These can additionally be proven by a set of useful indicators which allow further quantitative analysis and interpretation of the IC Report.

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