Management Accounting Research 15 (2004) 33–51

Management Accounting Research

www.elsevier.com/locate/mar

Managing and reporting knowledge-based resources and processes in research organisations: specifics, lessons learned and perspectives

Karl-Heinz Leitner [a,*], Campbell Warden [b]

[a] *Department of Technology Policy, Systems Research, ARC Seibersdorf Research GmbH, A-2444 Seibersdorf, Austria*
[b] *Instituto de Astrofisica de Canarias, E 38200 LA LAGUNA, Tenerife, Canary Islands, Spain*

Accepted 3 October 2003

Abstract

Across Europe, different kinds of research organisations are confronted with the challenge of managing their most valuable resources, which are knowledge based, in a more explicit and transparent manner. Over the last few years a small number of research organisations have started to implement new instruments for managing and measuring their knowledge-based resources and processes. The research organisations ARC (Austria) and DLR (Germany) have been the first European research organisations to publish Intellectual Capital Reports for their entire organisation, using a similar model, which addresses both the issues of internal management as well as external reporting. In both organisations, the newly established instruments are based on an indicator-based system. In this system, indicators about the different forms of Intellectual Capital (IC), the value-added processes and the results of the organisational knowledge-production processes, are integrated. Based on the experiences of implementing and running the system for 4 years, various aspects and the lessons that have been learned, are discussed. One of the main benefits of these IC measurement and reporting systems is that the organisations learn about their knowledge-production processes. However, there are some trade-offs between internal management use and external reporting, as well as limits in comparing indicators between organisations.

Keywords: Valuation of R&D; Intangible assets; Knowledge management; Research organisations; Accountability; Intellectual capital reports

1. Introduction

Research organisations are working in different fields, mainly in the areas of pre-competitive research, applied research and technology development. They can be characterised by their different kinds of own-

* Corresponding author. Tel.: +43-50550-3894; fax: +43-50550-3888.
E-mail address: karl-heinz.leitner@arcs.ac.at (K.-H. Leitner).

1044-5005/$ – see front matter
doi:10.1016/j.mar.2003.10.005

ership structures, different legal status, missions, organisational structures and outputs. The majority of them are non-profit, they often have missions and aims that are strongly influenced or even set by science and technology policy. Frequently they produce public goods. Research Organisations have public as well as also private owners and, although many are funded publicly, there is an increasing diversity of funding sources; including the private sector. Contract Research Organisations, Research Technology Organisations, Joint Research Centers, Competence Centers and Large-scale Research Infrastructures, are typical organisational forms. All these different types of organisations are labelled in this paper as "research organisations".

Research organisations have been confronted with new kinds of challenges in recent years. They have to compete increasingly for research funds and have to cope with new research modes (Gibbons et al., 1994). In many countries, there is a reorganisation of these establishments so that they serve the needs of industry more effectively; in particular, its demand for technological solutions (Arnold et al., 1998). The austerity policy of public funding bodies is forcing some research organisations to raise private funds via professional research contracts, mainly with industry. In some cases, this development goes hand in hand with new modes of financing. There are also situations where traditional institutional funding (where every organisation used to receive block grants from the public or governmental funding agencies) is being substituted with systems of programme funding; which are open to other organisations and for which research organisations have to apply on a competitive basis. Competition on commercial markets, market orientation and competitive-based funding, are thus becoming a new paradigm in this sector. This in turn also clearly demands a more progressive way of communicating with stakeholders, as well as measuring the performance of research organisations (Lindgren, 2001).

Furthermore, because of the still substantial funding through public institutions, there is an increasing demand for transparency about the use of public funds, going hand in hand with a growing demand for accountability; not only to the "owners" but also to customers and even citizens. Usually, as is the case in other knowledge-intensive sectors, research organisations are obliged to follow the national accounting standards with respect to the reporting of their intangible assets in their annual reports. For instance, according to the majority of national and international accounting standards, R&D investments can hardly be capitalised (e.g. IAS 38, SFAS 141/142). On the other hand, because of their legal status, some research organisations do not have to publish annual reports at all.

In reaction to these altered conditions, some research organisations have voluntarily started to introduce new management instruments in recent years and others may be obliged by governmental, or other, authorities to implement them in the future. These instruments range from cost-based accounting, Full Quality Management and professional research management, to Knowledge Management. In general terms, the "for profit" companies started implementing this kind of new management and accounting instruments earlier than the public research organisations (Edler et al., 2002). In recent years, some research organisations have also implemented managerial instruments based on indicators, such as the Balanced Scorecard (Kaplan and Norton, 1992) or the Intangible Asset Monitor (Sveiby, 1997).

Measuring and managing knowledge-based resources seems to have a huge potential for research organisations. Firstly, their most important resources are intangible ones and their major output is knowledge. Second the traditional accounting system does not produce clear information for investment decisions or the strategic management of knowledge-based resources. However, these instruments have not gained broad attention within these sectors; possibly due to the awareness of the complexity and problems of measuring knowledge-based processes, but more likely because of the common belief that science-based production cannot be managed (in the sense of classical management). Therefore, in order to introduce managerial and accounting instruments in these organisations these have to be adapted so as to meet the specific requirements of the value-added process.

In 1999, the Austrian Research Centers, Seibersdorf, was the first European research organisation to publish an IC report for the entire organisation. It was followed by the German DLR in 2000[1]. Both reports are based on a similar conceptual framework, developed within ARC. This allows the comparison of some indicators between these two organisations.

In the present paper, we will describe the specifics of IC management and reporting in research organisations and in particular the question of its impact on the production process and on their organisational performance. This will be evaluated on basis of the experience gained by ARC and DLR; currently, DLR has 2 years and ARC 4 years of experience with the new management and reporting system. Both organisations use a similar model, which was developed to address the specific circumstances of research organisations (see Leitner et al., 2002). The findings are primarily based on the experiences of one of the authors, who has been a member of the development team in both organisations since the outset.

At the beginning of this paper, we will present the model for IC management and reporting and will point out its features in comparison to other models and instruments described in the literature. So far, there exists hardly any literature on IC management and reporting in research organisations. After exemplifying the IC model, lessons learned from implementing and running the IC system will be summarised. The problems involved that have to be tackled when using the model for internal management decisions versus using it for external reporting, as well as its limits as regards the comparison of indicators between organisations and the differences to private industrial R&D departments, are discussed afterwards. Thus, the paper aims to highlight the features, the potential and the constraints of the instrument presented. Finally, the challenges for research organisations and research topics in this field that should be addressed in the future, will be illustrated.

2. A basic model for IC management and reporting for research organisations

IC management systems should provide information about the development and productive use of knowledge-based assets. Managers and investors should be supported in their decision making with knowledge that is based on financial and non-financial indicators. Two questions are crucial in order to accomplish this task (see Caddy, 2001; Lev, 2001). First, the demand for analysing the impact and financial returns of investments in IC. Second, the question of the relations and complementarities between different kinds of intangible assets. In recent years various models, methods and instruments for measuring, managing and reporting on intangible assets and IC have been proposed by academics and practitioners and these will now be described briefly.

Among the most widely used approaches for IC management and reporting are the so-called Intangible Asset Monitor by Sveiby (1997) and the IC approach by Edvinsson and Malone (1997), originally introduced by the insurance company Scandia. Thereby, the IC structure defines which categories of intellectual capital are differentiated and delivers assistance through a definition of indicators. While the Intangible Asset Monitor divides intangible assets into Internal Structure, External Structure and Competence, the Scandia Approach differentiates IC in Human Capital and Structural Capital, whereby

[1] The IC reports can be downloaded from http://www.arcs.ac.at/publik/fulltext/wissensbilanz and http://www.dlr.de.

the latter again is divided into Customer Capital and Organisational Capital. These different approaches are all similar in structure: Based on a model differentiating between the various forms of IC, each form is evaluated and subjected to descriptive interpretation, which, in turn, is based on indicators such as customer satisfaction, education, IT infrastructure, etc. However, there are a number of other classifications, each of which place their emphasis on particular 'groupings' of intangible assets or IC[2] (e.g. Saint-Onge, 1996; Steward, 1997; Sullivan, 2001).

In addition, some firms also use the Balanced Scorecard—originally developed for strategic management, control and performance measurement—for IC management and reporting (de Gooijer, 2000; Johanson et al., 2001; Bukh et al., 2002). This managerial instrument separates the financial perspective from different non-financial perspectives; originally customers, learning and growth and internal processes, and translates the corporate strategy into objectives and measures across these four balanced perspectives. Scandia, the first company to publish an IC report (1994), regards the IC report as the external representation of the Balanced Scorecard and thus decided to link every perspective of the Balanced Scorecard to an element of IC. In contrast to the above mentioned IC classifications the Balanced Scorecard emphasis that the corporate strategy is operationalised through indicators and hence expresses the relation between different kinds of the elements—perspectives—of the Balanced Scorecard (Kaplan and Norton, 1992). For each element of the Balanced Scorecard, key success factors are specified, for which, in turn, goals, indicators and measures are defined. With so-called 'strategy maps', cause-and-effect relationships between different key success factors can be illustrated. For instance, key success factors of Human Capital influence the efficiency of internal processes, which in turn influence the relations with customers and finally determines the financial performance. Apart from applying the explicitly labelled IC models and the Balanced Scorecard some firms, such as the Danish company Ramboll, uses the model of the European Foundation of Quality Management (EFQM) for measuring IC. This model distinguishes between enablers on the one hand and results on the other hand (Schneider, 1998).

However, the models available at present explain the relations between the different elements only to some extent. For instance, the classification by Scandia suggests a hierarchical relation between the elements, assuming that the different elements are additive. Other classifications do not conceptualise relations between different forms of IC. Moreover, the models do not clearly indicate how the different forms of IC are used in the value creation process, even though the explanation of their interaction is crucial. This is mainly explained by the firm's strategy, which is described in IC reports and is thus a necessary element for interpreting the indicators It is also highlighted by the various Guidelines for IC Reporting (MERITUM Project, 2002; Danish Ministry of Science, Technology and Innovation, 2003a,b; Nordic Industrial Fund, 2001) that have been published. In order to make the links between different forms of intangible assets and their relation to the results more explicit, firms frequently use (additional) instruments such as the Balanced Scorecard, value chain models (e.g. Normann, 2001), Total Quality Management systems (e.g. Schneider, 1998) and other performance management systems that have been proposed by academics and practitioners (e.g. Fitzgerald et al., 1991; Taylor and Convey, 1993). Within these instruments, the intangibles are often interpreted as drivers or enablers and their outputs as results. However, such models often seem too complex for external reporting. Moreover, none of the models is

[2] Even though there are intensive discussions about these terms, Intellectual Capital and intangible assets are used synonymously in this paper, as also proposed by some authors (e.g. Teece, 2000). In this paper, intellectual capital is defined as a non-physical resource which can be used to produce organisational outputs.

able to measure the flows between the different kinds of IC nor is the value which is generated through the combination of these intangibles measured by quantitative figures.

The instruments for IC management and reporting referred to above have been used within different kinds of industrial sectors such as the financial sector, manufacturing and services. Experiences of firms in various sectors and countries have been reported in recent years (e.g. Bukh et al., 1999; Backhuijs et al., 1999; Miller et al., 1999; Johanson et al., 2001). In contrast to the diffusion within industry, hardly any experiences or applications are reported from industrial R&D departments. Buckman (1998) is dealing with Knowledge Management in R&D labs, stressing the importance of organisational learning. However, there are some theoretical and empirical studies stressing that the outputs of industrial research processes in firms—mainly new products, patents and technical solutions—are the result of investments in various kinds of intangible assets, such as R&D and Human Resources (e.g. Baldwin and Johnson, 1996; Lev, 2001; Laursen and Foss, 2000; Bianchi et al., 2001). Henderson and Cockburn (1994) conclude from their empirical study about research processes in pharmaceutical firms that innovation results from R&D activities, HR and organisational assets. With respect to research organisations, Bueno (2002) presents a first list of indicators for IC management in research centres and universities for Human Capital, Structural Capital and Relational Capital. Breunig et al. (2002) developed a knowledge-based value creation model for research organisations, particularly addressing organisational learning. Experiences from higher education institutions (HEI) might also be of interest. However, there are hardly any experiences reported for HEI, except for instance Garnett (2001), who is dealing with learning environments in universities.

The IC model, is presented herewith, was developed to meet the specific requirements and attributes of research organisations. When designing the model, the development team within ARC was confronted with the question raised by both the Management and various external stakeholders, as to how knowledge-based assets could be managed and reported and how their impact could be measured (Leitner et al., 2002). Therefore, the IC model not only focuses on the different forms of intangible assets but also on the question as to how these investments are used by the organisation and how they influence the outputs of a research organisation. Since the models and instruments described above are not able to respond to these questions sufficiently, it was decided by the ARC management to design a new model which addresses these requirements.

Among the specific characteristics of research organisations are the facts that they are often non-for profit organisations and produce, to a certain degree, public goods. Moreover, research organisations are knowledge-based organisations per se, their most valuable investments are intangible ones and their outputs are knowledge based. Their output includes: innovative products, prototypes, patents, consultancy, providing research infrastructure, publications, and expert reports (Arnold et al., 1998). In accordance with the line of argument of the knowledge-based view of the firm, it can also be argued that, in the case of research organisations, combinations of intangible resources are the sources for the creation of new knowledge-based products (e.g. Grant, 1996; Cook and Brown, 1999).

For designing the model, not only the literature on IC management and reporting, but also the findings of innovation theory and evaluation, have been taken into account. This research stream copes with the innovation and research process of various organisations and proposes different process models for the innovation and research process in firms, research organisations and universities (Rothwell, 1994; Smith, 1997; Roessner, 2000). An interesting fact is that some authors distinguish between inputs, processes and outputs in measuring or evaluating the processes, such as Dodgson and Hinze (2000). The literature is quite helpful in gaining an understanding of the production process of a research organisation, even though it does not explicitly refer to IC.

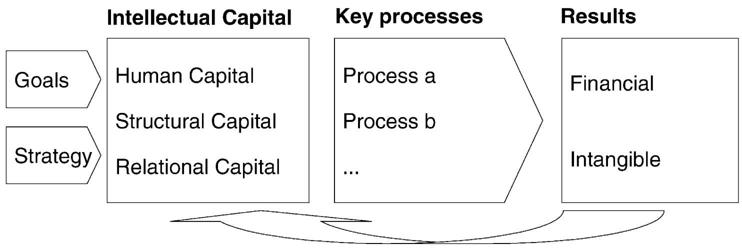

Fig. 1. Basic IC model for research organisations, generalised from the ARC IC model.

The IC model, which delivers the framework for the IC reports of ARC[3] and DLR[4] consists of four elements (see Fig. 1). It separates different forms of intangible assets or IC and links these to the organisational cycle of knowledge production within a research organisation. The logic of the IC model combines Goals, Intellectual Capital, Organisational Processes and Results. In the following paragraphs, we will describe each of the four elements of the model.

The process of acquiring, applying and exploiting knowledge starts with the definition of specific "Goals"; in both organisations these are labelled as "Knowledge Goals". Knowledge Goals define the areas where specific skills, structures, and relationships should be built up, or increased, to ensure that the corporate strategy can be implemented. These goals form the framework for the utilisation of the organisation's IC. Intellectual capital is composed of Structural, Human and Relational Capital. In adopting these components of IC, the ARC project team referred to the proposition of the MERITUM research group (MERITUM Project, 2002). These intangible resources, or IC, are the inputs (resources) for the knowledge-production process, which, in turn, is manifested in different kinds of projects or processes carried out by the organisation. In the case of research organisations, the processes are clearly different kinds of research activities, such as basic research, applied research and contract research projects, but also services and teaching.

In the case of ARC, the key processes have been defined as Independent Research and Contract Research Projects, which are the two fundamental project types within research organisations. Independent research is the long-term, pre-competitive research of ARC, organised in research programs, mainly financed by public funds, where the scientific basis for the projects for its customers are developed. Contract research projects are those projects, whether carried out for private or public customers, where specific problem solutions are generated. Spill-over is particularly important—i.e. interaction between

[3] Austrian Research Centers—ARC—is the biggest research organisation in Austria with public and private owners and is run as a private limited enterprise. ARC was founded as a nuclear research institution at the end of the 1950s and diversified its research range during the 1970s. Currently, ARC performs research and development in the fields of information technology, material technologies and engineering, life sciences, nuclear technology services and systems research and provides R&D services for industry and society.

[4] DLR is the German Aerospace Research Center and Space Agency. Primarily publicly funded, DLR is committed to government tasks and public concerns. Global research goals defined by the government are pursued in scientific autonomy. As a research enterprise, DLR aims to strengthen the competitiveness of German industry. Set up as a registered non-profit private society, co-funded by the Federal Ministry of Education and Research, DLR assumes sovereign tasks in its capacity as the German Space Agency. DLR has more than 4700 employees, of which 2300 are scientists. It has eight sites as well as offices abroad outside of Germany and consists of 31 research institutes, including test and operating facilities. The total budget for 2002 is 1153 Mio. €. The research activities of DLR concentrate on four sectors: Aeronautics, Space, Energy Technology and Transport Research and Technology.

independent research and contract research projects. This means that new knowledge is generated in the course of independent research that is then applied in contract research projects; leading in turn to benefits for private and public customers. Depending on the assignment or project, either all three elements of IC are utilised equally or individual elements are applied selectively in the different processes and projects.

The outputs of these different kinds of projects are various kinds of Results. Profit alone has limited value as a measure of the success of these projects. Therefore, the model integrates intangible results, which should include the whole range of outputs. In the case of ARC, these intangible results have been further refined in economy (industry)-, research- and society-oriented results. These three categories also reflect the major "customers" of the research organisation. The results are generally difficult to express in financial figures and may have a financial impact only at a later date. For instance, the outputs of a research organisation are often public goods and therefore not all outputs are sold commercially so that a price can be derived for a financial valuation. However, they might have various impacts on the economy and society in general, also referred to as "externalities". Therein lies a specific attribute in comparison to industrial firms and industrial R&D departments. These results are outputs of the organisation and measure its performance, but at the same time also enhance the organisation's IC. The arrow in Fig. 1 from the results to the IC and back, illustrates these knowledge flows.

The basic assumption of the model is that value is created when technological, human and organisational resources (IC) are aligned to enhance knowledge creation, sharing and exploitation within the R&D projects of a research organisation. This refers to the argument of the knowledge-based view of the firm, which states, "that firm specific resources are the foundation for the competitiveness of firms" (e.g. Grant, 1996). However, proponents of the knowledge-based view of the firm also argue, that highly firm-specific knowledge-based resources and their combination are the determinants for competitiveness and performance. Thus, the three elements of IC that are defined in the model have to be interpreted as the paramount elements. Hence, it is the specific attributes of a form of IC, as indicated by different measures, as well as the organisational strategy, which explain the uniqueness of an asset and its impact on the performance of a particular research organisation.

In contrast to other IC models developed in practice and/or theory, this model has obviously a strong 'process focus' since it explicitly separates Inputs, Processes and Outputs. The model should therefore be termed 'a process-oriented model'; combining corporate strategy, corporate knowledge goals and knowledge-based processes with intangible results. Thus, the user should be able to link the IC measures to the whole production process of an organisation. Through the integration of goals and the specific results, the particularities of research organisations and the difference between them and industrial firms should become transparent.

The model presented visualises the knowledge-production process for research organisations and can serve as a framework for knowledge management issues within various research organisations and can even be used for universities. When applying the model, organisations have to formulate explicitly the organisational goals relevant for the knowledge-based resources and processes. They have to define their key processes and, if requested, additional categories for the results. For instance, whereas ARC separates two processes (Independent Research and Contract Research Projects), DLR separates three processes, namely Program Research, Contract Projects, and Space Agency Management. Hence, the adoption of the model for the requirements of a specific organisation requires a discussion about corporate strategy and the identification of the key processes. Herein lies the main managerial challenge for organisations adopting the IC model.

3. The implementation process in the research organisations ARC and DLR

ARC and DLR had similar motivations for the implementation of their IC management and reporting system[5]. ARC has gone through a reorganisation process since the mid-1990s caused by the new objectives adopted by the owner, new funding mechanisms and increased competition. ARC thus introduced a range of new management instruments, ranging from the ISO 9000 certification, the professionalisation of the research program's management and process cost accounting. ARC defined itself as a 'knowledge enterprise' in 1998. The implementation of an IC management and reporting instrument was the logical step within this development. In 1999 the management decided to implement an IC report. The ARC IC Report has been compiled to meet the following explicit project objective: "to illustrate the development of intangible assets, to explain the achievements of research and their benefits to stakeholders and to create transparency about the use of public funds".

DLR started with the implementation of its first IC report in 2000. The original motivation for the implementation of the IC report was to replace the so-called Innovation Report, a report which most German public research organisations have to publish annually for Germany's Federal Ministry of Education and Research. With the new IC reporting system, DLR addressed the demand for a more comprehensive reporting to its owner, the Ministry of Education and Research, but also to other stakeholders. Moreover, DLR aimed to link the newly published indicators closely to the indicators used for strategic management and accounting.

The annual analysis and interpretation of IC indicators is intended to increase transparency and control the value-added process within the two organisations. Besides the primary aim to serve as a communication and reporting instrument for the external stakeholders, it was soon realised that the IC report also delivers rich information for strategic management. Based on the awareness for the potential of IC reporting to monitor the achievement of goals, it was decided in both organisations to link the IC indicators directly to the knowledge goals to measure their realisation within the IC report.

The implementation process consisted of three phases, the definition of the knowledge goals, the definition of indicators and gathering of data and the preparation of the report. The definition of knowledge goals was based on the corporate goals and strategies within the organisations. The term knowledge goals should express the importance of the new kinds of corporate goals, referring to the development of intangibles. ARC's knowledge goals are summarised under the headings "Knowledge transfer", "Interdisciplinarity", "Research Management", "Internationality" and "Spin-offs", expressing the corporate objectives with respect to the development and exploitation in the main knowledge areas. DLR reformulated its corporate goals and strategies in a broad dialogue across the organisation in 1999, which served as point of departure for the whole development. Finally, five knowledge goals were formulated, summed up as "Exploiting Knowledge", "Striving for Excellence", "Staff Development", before Establishing Networks", and "Encouraging Innovation".

Apart from the knowledge goals, which served as a basis for this project step, the existing data within the organisation was another element of reference for the definition of indicators. The aim was to formulate valid indicators for every element of the model (see Appendix A). Both organisations selected about 60 indicators. The majority of them already existed in the organisations, about 20% had been newly defined and had to be gathered separately. After the definition of indicators the data gathered was interpreted, referring to available past data and the defined knowledge goals.

[5] For an overview of the experiences within ARC, see Koch et al. (2000), for DLR see Rudolph and Leitner (2002).

When defining and selecting indicators, the team tried to use indicators that had been defined and proposed by the literature on innovation and research evaluation in order to enhance the comparability with other organisations (e.g. OECD, 1998; Dodgson and Hinze, 2000; Grupp, 2000; Foray, 2000).

4. The implementation process: lessons learned

When reflecting on the experiences with the implementation of the IC reports published so far by ARC and DLR, some conclusions can be drawn. In general, (i) the appropriateness of initiating the process with the goals, and (ii) the process followed to select the indicators, are essential.

The starting point and an essential task for implementing an IC measurement system, is the discussion of corporate goals and strategies. Compared to the traditional balance sheet, the development of an IC Report requires the explicit formulation of organisational goals. This task is usually not easy and the goals and strategies that are formulated are often too vague to set the framework for the later job of defining indicators. In the process of carrying out this task, the team also learned that the implementation of goals was difficult due to the characteristics of the research process. Instead of specifying rigid targets, which is often problematic for scientific research and might restrict business activity, the goals were interpreted as ‘corridors’, which define the rough direction of development and allow more room for evolution. Nevertheless, this framework could also be defined more precisely and implemented by means of indicators. The indicators assigned to Human Capital, Structural Capital and Relational Capital therefore measure to some extent the organisational framework conditions for achieving results in the future. Thus, it is more the definition of these conditions and the “fertility” of the soil in which, at a later point in time, innovative results can be achieved.

After defining the knowledge goals, the project teams started to formulate the indicators for the report. However, the ideal way of defining indicators, derived from goals, was not always possible. Sometimes information and indicators which existed in different departments had to be evaluated on the basis of their relevance for the task of valuing intangibles. The development of the indicators was the combination of top-down and bottom-up processes.

One of the biggest dangers when developing an IC Report is to define too many goals or indicators. If neither the picture of the company’s future development nor the important intangible resources required are clear, people or organisations tend to want “everything”. However, strategic thinking entails setting priorities. In the case of ARC it was possible to reduce the original list of more than 200 potential indicators to about 60. The problem of defining too many goals and indicators is also highlighted in empirical studies carried out in industry regarding the introduction of management accounting systems such as the Balanced Scorecard. Such studies delivered some evidence that indicator systems helped the firms to make their corporate goals and strategies more concrete and measurable, which also seems to be true in the context of research organisations (e.g. Hoque and James, 1999). In the future, both organisations will try to reduce their list of indicators and improve the elimination of redundancies within the system of indicators, the balance of indicators between the categories and the understanding of input–output relationships of indicators.

A further complicating element is that IC indicators can measure different things and sometimes similar resources and results. An example should illustrate the problem: The indicator “number of lectures per scientific employee” is, for example, a measurement of knowledge transfer to students, a measurement to value the opportunities for networking, and even a measurement for competence enhancement of the lecturer. Thus, when selecting indicators, a priority must be to define them as exactly and transparently as possible, which is also stressed in the literature (Eccles, 1991; Atkinson et al., 1997).

When "reading" the IC Report, a variety of interpretations are possible. This range of possible interpretations is wider than that of the Balance Sheet or Annual Report, where common standards and experiences already exist. For the interpretation of the indicators it is essential to find a common language, which means that all stakeholders refer to the same framework. In general, assessments can be made (i) on the basis of the development over consecutive periods, (ii) by comparing with the formulated goals or (iii) by benchmarking with similar research organisations.

5. Discussion

5.1. *Structure-oriented versus process-oriented models*

Previous models for IC management and reporting usually classify different forms of IC and partly illustrate the relations between them. Therefore these should be labelled "structure-oriented" models. Whereas the model presented here should be defined as a "process-oriented" model, insofar as it incorporates IC within the knowledge-production process of research organisations. The model depicted in this article is thus similar to the process logic of the EFQM model. Yet, in comparison to the EFQM model, it explicitly integrates different forms of IC. In the recent literature, some authors have proposed similar, more process-oriented models for measuring intangible assets. Lev (2001), for instance, calls for the 'value chain blueprint', whereby firms should report on non-financial value drivers along the innovation chain. Müller-Stewens (1998) proposes to separate the different indicators of performance measurement systems to inputs, processes, and outputs according to the four stakeholders' perspectives: Employees, Customers, Shareholders and Society.

The IC model presented here is a linear one and visualises the knowledge-production process through an input–output logic. Intangible assets are the inputs and resources of a research organisation, yet, at the same time, the outputs that a research organisation produces, such as patents, new products, etc., are also partly intangible assets and enhance the knowledge base of the research organisation. Insofar as knowledge-based outputs also enhance the knowledge base of intangible assets of an organisation and allow it to build up its knowledge base, it can be interpreted as a cyclical one. The fact that investments in intangibles generate new intangible assets is stated in the literature. Lev (2001), for instance, argues that intangible assets are simultaneously assets and generators of assets. Bianchi et al. (2001) proposes that intangible assets can be both inputs and outputs, and Kingsley and Melkers (1999) interpret various outputs of publicly funded research programs as forms of IC.

The processes of the model are the various activities and projects carried out in an organisation which combine the different intangible assets. In the case of the two research organisations, these are mainly research projects for various customers. Processes are measured by different indicators that describe the nature and development of the research projects. Even though the relations between the processes are not measured, in both organisations the Management discussed the possible knowledge spill-overs between the processes. In the end, an organisation produces different kinds of outputs, measured by indicators in different categories. By comparing inputs and outputs between different periods, information could be gained about the returns on intangible investments.

The IC model proposed in this article does not present a visualisation of complex relationships or flows between the various elements. It suggests that all three forms of IC are important pillars for the different processes of the organisations and does not see specific forms of IC as the starting point of the value creation process, as for instance, is visualised in the strategic maps of the Balanced Scorecard. For instance, firms often start with customers or the learning perspectives (Bukh et al., 2002; Norreklit, 2000). With the model presented, it is neither possible to trace knowledge flows between different kinds of resources and projects, nor to quantify the link between inputs and outputs by financial figures and yet it manages to capture the complexity of the knowledge-production process as well as defining a limited set of indicators. The process character of the underlying model should help to address, or raise the awareness, of flows between different kinds of inputs or resources, various processes and results. In addition, when interpreting input–output data of IC measurement systems, one has to consider that in a science-based organisation the time lag between investing in intangibles and achieving the results—the knowledge-production cycle—can last quite a long time. Thus, increased investments in Human Capital or Relational Capital can cause better results after 2 or 3 years. The development of the stocks of IC can thus only be traced over the years by comparing the figures. The time period of 4 and 2 years, respectively, of the two organisations discussed, will allow a complete analysis in the future.

Finally, like most other approaches for IC measurement, the model presented is not directly compatible with, or cannot be incorporated into, the classical financial accounting system. Perhaps it should be the other way around with the IC report containing qualitative, quantitative and financial information. In this way, it would provide an overall, although not necessarily integrated, picture of what a research organisation has achieved and how it is using its resources to achieve further value creation.

5.2. External reporting versus managing intangible assets

The IC management and reporting system in ARC and DLR serves as both a Management and Communication instrument. With respect to external communication, the publication of data concerning intangible assets contributes to the establishment of trust as one of the most important ingredients for long term organisational strategies. On the other hand, the fear of losing stakeholder commitment and in the end also financial support, is clearly a barrier in the process of convincing other research organisations of the value of implementing this new instrument.

The underlying IC model contributes to an improved understanding of the knowledge-production process within the organisation. It helps deal with investment decisions by its separation into goals, inputs, processes and outputs. The comparison of data between the two organisations as well as between different divisions within an organisation, indicates that the valuation of IC indicators is dependent on the specific goals and the context of departments, which is also heavily stressed by the IC literature (e.g. Roberts, 1999). For internal management purposes, one thus needs a more disaggregated system which can be used to produce disaggregated indicators and goals. This is indeed being done in both organisations.

Obviously, some trade-off might emerge with the two aims to serve both as a Management Instrument for the organisation itself and also as a Communication Tool with stakeholders. One the one hand, research organisations will not be willing to deliver sensitive information if they fear that this will have negative consequences for their funding. In the case of research organisations, the owners are also mostly the primary funding institutions. The problem of tactical behaviour due to evaluations is recognised in the literature, especially if results are bound to financial allocation mechanisms (Blalock, 1999). On the other hand, more sophisticated and detailed information, also at the departmental level, are important in order to facilitate organisational learning (Kaplan and Norton, 2000).

5.3. Commonly defined indicators versus specific indicators

In the case of both DLR and ARC, when developing their IC reports, both organisations had in mind the goal of being able to compare their data and consequently tried to use an equal set of indicators. One principle for the definition of the indicator set was, if possible, to use relative indicators, for example, expressed as percentage of turnover, or the relation to the number of total scientific researchers, etc. in order to allow the simple comparison of the data. This is still an ongoing process and, obviously, because of the context and goal dependency, not all indicators are relevant for both organisations and have thus to be interpreted differently. However, a set of common indicators has been defined. Roughly 30% of all indicators are used by both organisations within their IC reports. The full list of comparable IC figures of DLR and ARC for the year 2001 can be found in Appendix A.

In general, there are some indicators which have similar values, while others express considerable differences. When interpreting the two IC sets, some differences emerge, which considering the different goals is to be expected. For instance, in the field of Human Capital some indicators facilitate a comparison of their development. The total annual fluctuation of the employees at DLR is about 19%. This is a high value compared to the 11% at ARC, which can be explained by the strategic goal of DLR to adjust the ratio of permanent contracts to temporary contracts for scientific staff at institutes to 1:1 and in facilities to 2:1. This figure is also influenced by the labour law applied for the DLR, since permanent contracts at DLR are de facto tenures.

Another example can be derived from the Relational Capital. Teaching assignments by the staff is a central element of DLR’s personnel policy to intensify co-operation and secure access to the next generation of scientists. This is an indicator of the tight link to universities. Obviously, this is not the case for ARC, where only a minority of the institute directors are also engaged at universities. This was not an explicit strategy of ARC in the past and it is currently being reviewed. The number of conference meetings per researcher is high in both organisations and expresses the importance of fostering the relationship networks. Finally, the international commitment of DLR is extremely high, with the respective indicators reflecting these goals and its performance. ARC has followed the strategy of stronger international engagement for a few years, but the extent of its international business is still lower (e.g. projects for foreign customers). However, both organisations are successfully integrated in EC funded projects.

While both organisations and also other research establishments, industrial R&D departments and universities, get information for their own management tasks and decisions, there are limits to the comparability and transferability of the published data. First, there are limits as to what can be published at all in an IC report because of the sheer nature of knowledge: not everything can be made explicit in terms of figures, not to mention the question of validity of the reports. Often the context of the data, necessary for reasonable interpretation, is missing.

Second, the complex nature of the process cannot be captured. The measurement of the results and performance is focused on a limited set of output indicators. Different research organisations pursue different aims, their published data have thus to be analysed considering the individual aims as well as the broader context. Thus, it has become obvious that a set of commonly defined indicators is needed. In addition, there is also a need for individual indicators, which reflect specific strategies and aims of the different organisations.

5.4. *Research organisations versus industrial firms*

Value-added processes, in the case of research organisations and their R&D, are complex processes. Consequently, instruments for measuring and reporting in different research organisations, industrial R&D departments and labs, high-tech firms, spin-offs, universities, etc. have to reflect the specific context and aims by explicitly defined goals and indicators. The IC model presented explicitly tries to express the various kinds of results, as in the case of ARC and DLR, classified as economy (industry)-, research- and society-oriented research results. This focus also reflects the difference when compared with the IC reports of industrial firms or R&D departments of industrial firms. The model identifies non-financial results which are classified as economy (industry)-, research- or society-oriented, as used by ARC and DLR. This classification reflects the three main target groups of the two research organisations namely the economy, de facto private firms, the scientific community and society in general.

In industrial firms, the outputs and results of the R&D activities are the input for further processes in the value chain or the innovation process when building up large-scale production, organising sales and marketing, etc. In the end, the R&D results of firms are incorporated into products, sold by the company which thus increase the revenue and profits of the firm and amortise the R&D investments. In contrast, in research organisations the various research results are the end product itself. They usually do not produce products on a large scale, which is necessary for the amortisation of R&D investments in private firms. Research organisations often contribute to the early stages of the innovation process of various customers within the national innovation system and serve thus as an important research infrastructure, with no explicit profit motive (Smith, 1997). The “customers”, who sometimes are not even known to the company, as for example in the case of producing public goods or services, use and apply these research results for their own business and problem solutions. This is an additional reason for the complexity and difficulty of measuring research results only by financial figures, because the externalities can hardly be allocated to the research organisation itself (Williams and Rank, 1998).

Finally, private R&D departments can learn from research organisations and vice versa regarding the measurement and management of complex research processes. In the context of a planned benchmarking initiative by ARC and DLR, it might be of interest to have some indicators in common with other sectors in the future.

6. Summary and perspectives

The model presented for IC management and the experiences involved with the implementation of this instrument in two European research organisations are to provide some initial insights into how the production process could be conceptualised in a research organisation. From the conceptual point of view, the IC model incorporates a classification proposed in the literature (MERITUM Project, 2002) with the process logic of organisational research processes, proposed within the literature on innovation and research evaluation (see Rothwell, 1994). Thus, the IC model is able to visualise the knowledge-production process of research organisations. Both organisations were able to learn about their knowledge-production process since, for the first time, data could be gathered from inputs, processes and outputs simultaneously—information which the traditional financial accounting system, as well as various other IC models exemplified in the literature, fail to deliver.

As illustrated, even though the model is simply abstracting a linear model, it allowed structured discussions within management and fits the requirements for external reporting. For internal management tasks, the model has to be more fully defined and additional indicators are needed. In addition, the IC model might also be useful to industrial firms and industrial R&D departments, defining especially the key processes of a company and reflecting the value chain or business model to some extent.

Despite the first success within ARC and DLR, three major development tracks are seen for the future in order to diffuse and elaborate instruments for IC management within the research sector. Firstly, the theoretical and methodological development has to be carried on. Secondly, a commonly agreed definition of a set of indicators is needed. Thirdly, guidelines for the development of IC management systems and analysis of the published data are required.

In line with the knowledge-based theory of the firm, the model presented considers that, "intangible resources are the cornerstone for the competitiveness and output of research organisations". In order to understand the productive use of the intangible investments and their impact, one has to consider the value-added processes of an organisation. The better understanding of the production process within this sector—some 'theory of knowledge production in science-driven organisations'—is the prerequisite for the improvement and explanatory power of IC reports and measurement systems and would also allow the meaningful interpretation of the data that is published. In addition, the lack of understanding of the knowledge-production process within research organisations and their 'business models' also limits the adequate use and diffusion of IC measurement systems. Promising approaches to conceptualise better the knowledge-production process in research organisations can be found in the literature on Knowledge Management (e.g. Cook and Brown, 1999). Yet, until now hardly any studies have been carried out in research organisations which have applied theories of the firm. Even though there is some literature on scientific productivity (e.g. Middlaugh, 2002), organisational theory in research establishments (e.g. Cohen et al., 1972) and research evaluation (e.g. Blalock, 1999), there is no integrated conceptual framework or 'firm-theory' available which could explain the production process of research organisations. Thus, there seems to be a huge demand for further theoretical and methodological work in order to improve the understanding of the underlying principles of these kinds of organisations.

In order to analyse input–output relations more thoroughly, statistical methods might be used in the future in both organisations, if a sufficient amount of data becomes available. Moreover, based on a better theoretical framework, empirical studies should be carried out to analyse such relations. Such studies have been carried out in industry for a long time on the impact of various intangible investments or factors and their impact on performance (e.g. Henderson and Cockburn, 1994; Michie and Sheehan, 1999; Bontis, 2002), which serve as a reference. More sophisticated quantitative models such as Data Envelopment Analysis (DEA), which is used to analyse input–output relations, might be beneficial. In the past, these models were used for various applications, also for performance measurement (e.g. Fuertes et al., 2002). DEA is especially useful for variables which have different scales as is the case with the IC measurement systems presented.

The second research and development path lies in the definition of commonly defined indicators which allows managers and stakeholders to compare IC measures. Based on the co-operation of both organisations, the IC teams of ARC and DLR were able to define a common set of IC measurements and are able to compare some of their IC indicators. This definition and selection of indicators should be guided by empirical studies and should deliver those indicators with the strongest explanatory power. Such indicators have been proposed for industrial firms for instance by Lev (2001). For the development of the indicators used in ARC and DLR, the team referred to the work in the field of innovation systems and evaluation research. This literature proposes indicators of high relevance for IC measurement systems, the comparison of data, and their aggregation for macro-economic and policy-oriented use. As illustrated, even though indicators are firm and strategy dependent, based on equally defined indicators, more sophisticated interpretations are possible. In particular, it is possible for managers to learn from other firms. It is also necessary to note that existing accounting systems and management routines, as well as regulations, in both DLR and ARC, hinder the harmonisation of the indicators. However, a broader initiative for the whole sector across and beyond Europe is needed to raise the general level of awareness and to elaborate the methodology and define relevant indicators[6].

Thirdly, it is necessary to establish guidelines for developing and interpreting IC Reports for research organisations. The MERITUM Guidelines (MERITUM Project, 2002), Danish guidelines for IC reporting (Danish Ministry of Science, Technology and Innovation, 2003a,b), and NFF guidelines (Nordic Industrial Fund, 2001) may serve as examples. The guidelines for research organisations can build upon these but have to incorporate findings from the theoretical and empirical studies in research organisations as presented here. This will require not only a commonly accepted IC model that would benefit from its wider implementation, but also to deliver some support for the reading and interpreting of published data, again based on the improved theory-based understanding of relations between inputs and outputs. Once more, again the Danish guidelines for "Analyzing Intellectual Capital Statements" could serve as example (Danish Ministry of Science, Technology and Innovation, 2003a,b).

Acknowledgements

We acknowledge very helpful comments form Bernd Rudolph, Thomas Rödiger-Schluga, Manfred Bornemann, and two anonymous referees.

Appendix A. List of selected IC indicators of ARC and DLR for 2001

	DLR	ARC
Intellectual capital		
Human capital		
Number of staff	4,776	384
Total scientific staff	1,641	215
Fluctuation (%)	19	11
Retirement	914	42
Average length of employment in years	11.0	11.3
Personnel expenditure as a percentage of total expenditure	55	45
Percentage of women		
Total	28	22
In management positions	11	2.6

[6] In order to increase the awareness among Higher Education Institutions and Research Organisations (HERO) of new managerial and reporting tools, the European Association of Research Managers and Administrators (EARMA) has launched, in cooperation with relevant stakeholders, an international network and a Working Group for Valuing and Managing Intangibles. See http://www.earma.org/WG/vimak/vimak.html.

Appendix A. (*Continued*)

	DLR	ARC
Scientific staff	12	13
Ratio of permanent contracts to temporary contracts (for scientific staff)	1.0	7.4
Training days per employee	1.7 (internal)	5.19
Structural capital		
Total IT expenditure per employee in EUR	9,800	2,569
Teleworking jobs	61	0
Relational capital		
Foreign assignments (months)	423	12
Institute directors holding teaching assignments (%)	100	50
Visiting scientists (stay >1 month) as a percentage of the number of scientific employees	6.3	5.6
Processes		
Program research		
Government-funded research as a percentage of total income	54	37
Contract projects/applied research projects		
Third-party funding as a percentage of total turnover	46	63
Percentage of new contracts with inter-institute co-operation	6.7	4.1
Projects for foreign customers (% income volume)	30	22
Results		
Financial results		
Competitive-based funds (third-party funds)	46	63
Research-oriented results		
Publications in referred journals (per scientific employee in institutes and facilities)	0.33	0.33
Lectures (per scientific employee)	0.87	1.79
Appointments to professorships at universities and colleges	0.08	0.19
Habilitations (post-doctoral dissertations)	1	1
Number of projects supported by the largest national research promotion fund	37	4
Success rate of EU proposals in the last 3 years (accepted/submitted) (%)	40	27
Ratio of prime contractor/total EU-projects (%)	8	16
Economy-oriented results		
Total number of patent applications	124	16
Number of patents granted per scientific employee ($\times$100)	12.1	0.93
Income from licences in 1.000 EUR	33,000	45
Number of spin-offs	8	1
Society-oriented results		
Number of internet site hits by external users per month in Mio.	2.4	0.3

References

Arnold, E., Rush, H., Bessant, J., Hobday, M., 1998. Strategic planning in Research and Technology Institutes. R&D Manage. 28 (2), 89–100.

Atkinson, A.A., Waterhouse, H.H., Wells, R.B., 1997. A stakeholder approach to strategic performance management. Sloan Manage. Rev. 38 (Spring), 25–37.

Austrian Research Centers Seibersdorf, 2000. Intellectual Capital Report 1999. Seibersdorf. Available on the website http://www.

Backhuijs, J.B., Holterman, W.G., Outman, R.S., et al., 1999. Reporting on intangible assets. In: Paper Presented at the OECD International Symposium on "Measuring and Reporting Intellectual Capital: Experiences, Issues, and Prospects", 9–10 June, OECD, Amsterdam.

Baldwin, J.R., Johnson, J., 1996. Business strategies in more- and less-innovative firms in Canada. Res. Pol. 25, 785–804.

Bianchi, P., Iorio, R., Labory, S., Malagoli, N., 2001. EU policies for innovation and knowledge diffusion. In: Report Produced for the EU PRISM Research Project, University of Ferrara.

Blalock, A.B., 1999. Evaluation research and the performance management movement. Evaluation 5 (2), 117–149.

Bontis, N., 2002, Intellectual capital. An exploratory study that develops measures and models. In: Wei, C., Bontis, N. (Eds.), The Strategic Management of Intellectual Capital and Organizational Knowledge. Oxford University Press, Oxford, pp. 643–655.

Buckman, R.H., 1998. Knowledge sharing at Buckman Labs. J. Bus. Strategy 1, 11–15.

Bukh, P.N., Johansen, M.E., Mouritsen, J., 2002. Multiple integrated performance management systems: IC and BSC in a software company. Singapore Manage. Rev. 24 (3), 21–33.

Bukh, P.N., Larsen, H., Mouritsen, J., 1999. Developing intellectual capital statements: lessons learned form 23 Danish firms. In: Paper Presented at the OECD International Symposium on "Measuring and Reporting Intellectual Capital: Experiences, Issues, and Prospects", OECD, 9–10 June, Amsterdam.

Bueno, E., 2002. IC and scientific production of the Madrid research centers. In: Paper Presented at the Conference "The Transparent Enterprise. The Value of Intangibles", 25–26 November, Madrid.

Breunig, K.J., Skaret, M., Ulleberg, T., 2002. Pillars of connectivity. The continuous drama of assessing large issues when deciding on lesser ones. In: Paper Presented at the Conference "The Transparent Enterprise. The Value of Intangibles", 25–26 November, Madrid.

Caddy, I., 2001. Issues concerning intellectual capital metrics and measurement of intellectual capital. Singapore Manage. Rev. 24 (3), 77–88.

Cohen, M.D., March, J.G., Olsen, J.P., 1972. The garbage can model of organizational choice. Admin. Sci. Quart. 17, 1–25.

Cook, S.D.N., Brown, J.S., 1999. Bridging epistomologies: the generative dance between organizational knowledge and organizational knowing. Organ. Sci. 10, 4.

Danish Ministry of Science, Technology and Innovation, 2003a. Intellectual Capital Statements. The New Guideline. Copenhagen.

Danish Ministry of Science, Technology and Innovation, 2003b. Analyzing Intellectual Capital Statements. Copenhagen.

Deutsches Zentrum für Luft- und Raumfahrt DLR, 2001. Intellectual Capital Report 2000, Köln 2001.

de Gooijer, J., 2000. Designing a knowledge management performance framework. J. Knowledge Manage. 4 (4), 303–310.

Dodgson, M., Hinze, S., 2000. Indicators used to measure the innovation process: defects and possible remedies. Res. Eval. 8 (2), 101–114.

Eccles, R.G., 1991. The performance measurement manifesto. Harvard Bus. Rev. 70, 20–24.

Edler, J., Meyer-Krahmer, F., Reger, G., 2002. Changes in the strategic management of technology: results of a global benchmarking study. R&D Manage. 32 (2), 149–164.

Edvinsson, L., Malone, M., 1997. Intellectual Capital, Realising Your Company's True Value by Findings its Hidden Brainpower. New York.

European Foundation for Quality Management, 2003. URL: http://www.efqm.org/.

Fitzgerald, L., Johnston, R., Brignall, S., Silvestro, R., Voss, C., 1991. Performance Measurement in Service Business. Cambridge.

Foray, D., 2000. Characterising the knowledge base: available and missing indicators. In: OECD, 2000. Knowledge Management in the Learning society. OECD, Paris, pp. 239–257.

Fuertes, Y., Mar, C., Serrano, S., 2002. Measuring DEA efficiency in internet companies. In: Paper Prepared for the Conference "The Transparent Enterprise. The Value of Intangibles", Autonomous University of Madrid, Ministry of Economy, 25–26 November, 2002, Madrid, Spain.

Garnett, J., 2001. Work based learning and the intellectual capital of universities and employers. Learning Organ. 8 (2), 78–81.
Gibbons, M., Limoges, C., Nowotny, H., 1994. The New Production of Knowledge. Pinter Publishers, London and New York.
Grant, R.M., 1996. Towards a knowledge-based theory of the firm. Strategic Manage. J. 17, 109–122.
Grupp, H., 2000. Indicator-assisted evaluation of R&E programmes: possibilities, state of the art and case studies. Res. Eval. 8 (2), 87–99.
Henderson, R., Cockburn, I., 1994. Measuring competence? Exploring firm effects in pharmaceutical research. Strategic Manage. J. 15, 63–84.
Hoque, Z., James, W., 1999. Strategic priorities, balanced scorecard measures and their interaction with organizational effectiveness: an empirical investigation. British Accounting Association, Annual Conference, 29–31 March 1999, University of Glasgow.
Johanson, U., Martensson, M., Skoog, M., 2001. Measuring to understand intangible performance drivers. Europ. Acc. Rev. 10 (3), 407–437.
Kaplan, R.S., Norton, D.P., 1992. The Balanced Scorecard—measures that drive performance. Harvard Bus. Rev. 70 (1), 71–79.
Kaplan, R.S, Norton, D.P., 2000. Double-Loop Management: Making Strategy a Continuous Process. Balanced Scorecard Report. Harvard Business School, Boston.
Kingsley, G., Melkers, J., 1999. Value mapping social capital outcomes in state research and development programs. Res. Eval. 8 (3), 165–176.
Koch, G., Leitner, K-H., Bornemann, M., 2000. Measuring and reporting intangible assets and results in a European Contract Research Organisation. In: Paper Prepared for the Joint German-OECD Conference “Benchmarking Industry-Science Relationships”, 16–17 October 2000, Berlin.
Laursen, K., Foss, N.J., 2000. New HRM practices, complementarities, and the impact on innovation performance. Working paper. Department of Industrial Economics and Strategy, Copenhagen Business School.
Leitner, K.H., Bornemann, M., Schneider, U., 2002. Development and implementation of an Intellectual Capital Report for a Research Technology Organisation. In: Bontis, N., (Eds.), World Congress on Intellectual Capital Readings. Butterworth, Heinemann, pp. 266–285.
Lev, B., 2001. Intangibles, Management, Measurement, and Reporting. Brookings Institution Press, New York.
Lindgren, L., 2001. The non-profit sector meets the performance-management movement. Evaluation 7 (3), 285–303.
MERITUM Project, 2002. Guidelines for Managing and Reporting on Intangibles (Intellectual Capital Report), January, Madrid.
Michie, J., Sheehan, M., 1999. HRM practices, R&D expenditure and innovative investment: evidence form the UK’s 1990 workplace industrial relations survey. Ind. Corp. Change 8, 211–234.
Middlaugh, M.F., 2002. Understanding Faculty Productivity. San Francisco.
Miller, M., DuPont, B., Fera, V., et al., 1999. Measuring and reporting intellectual capital from a divers Canadian industry perspective. In: Paper Presented at the OECD International Symposium on “Measuring and Reporting Intellectual Capital: Experiences, Issues, and Prospects”, 9–10 June, OECD, Amsterdam.
Müller-Stewens, G., 1998. Performance measurement in lichte eines stakeholderansatzes. In: Renecke, S., Dittrich, D. (Eds.), Marketingcontrolling. St. Gallen, pp. 34–43.
Nordic Industrial Fund, 2001. Intellectual capital managing and reporting. A Nordika project. Available at: www.nordicinnovation.net.
Normann, R., 2001. Reframing Business. When the Map Changes the Landscape. Wiley, New York.
Norreklit, H., 2000. The balance on the balanced scorecard a critical analysis of some of its assumptions. Manage. Acc. Res. 11 (1), 65–88.
OECD, 1998. Main Science and Technology Indicators. OECD, Paris.
Rudolph, B., Leitner, K.H. 2002. Research organisations discover their intellectual capital: experiences of the organisations DLR and ARC and the potential for comparing IC measures. In: Paper Prepared for the Conference “The Transparent Enterprise. The Value of Intangibles”, Autonomous University of Madrid, Ministry of Economy, 25–26 November 2002, Madrid, Spain.
Roberts, H., 1999. The control of intangibles in the knowledge-intensive firm. In: Paper Presented to the 22nd Annual Congress of the European Accounting Association, Bordeaux.
Roessner, D., 2000. Quantitative and qualitative methods and measures in the evaluation of research. Res. Eval. 8 (2), 125–132.
Rothwell, R., 1994. Industrial innovation: success, strategy, trends. In: Dodgson, M., Rothwell, R. (Eds.), The Handbook of Industrial Innovation. Edward Elgar, Cheltenham.
Schneider, J.M., 1998. Unternehmensbewertung nach dem EFQM-modell—eine neue form des controlling. Controller Magazin 23, 5.

Saint-Onge, H., 1996. Tacit knowledge: the key to strategic alignment of intellectual capital. Planning Rev. 24 (2), 10–14.
Smith, K., 1997. Economic Infrastructure and innovation systems. In: Edquist, C. (Eds.), Systems of Innovation: Technologies, Institutions and Organizations. Pinter, London, pp. 87–105.
Steward, T., 1997. Intellectual Capital. The Wealth of Organizations. London.
Sullivan, P., 2001. Value-driven Intellectual Capital. Wiley, London.
Sveiby, K.E., 1997. The new organizational wealth: managing and measuring knowledge-based assets. Berrett-Koehler, San Francisco.
Teece, D., 2000. Managing Intellectual Capital. Oxford University Press, Oxford.
Taylor, L., Convey, S., 1993. Making performance measurement meaningful to the performers. Canadian Manager, Fall, 22–24.
Williams, D., Rank, D., 1998. Measuring the economic benefits of research and development: the current state of the art. Res. Eval. 7 (1), 17–30.