Developing performance measures and setting their targets for national research institutes based on strategy maps

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Abstract

Purpose – This paper aims to help research managers design the performance management process and select measures and indicators, which relate to the strategies of their organisations directly.

Design/methodology/approach – In this paper, we will propose strategy maps for national research institutes (NRIs), so that the managers can describe the strategies of their organisations more clearly, accurately and logically. Also, we will propose a new method to set targets for key performance indicators (KPIs), which is named “Forecasting-Objective Achievement System (FOAS)”.

Findings – The authors have explored the general rules of the research activity and proposed the strategic map for NRIs, so that the research managers can more clearly, accurately and logically describe the strategy for the organisational development strategy, and build the performance measurement indicators based on it. It allows the managers to transfer the strategy into clear and concrete action initiatives, and the corresponding performance evaluation indicators. Also, this paper proposed a new method for target-setting for performance indicator to drive NRIs do their best to achieve high performance.

Research limitations/implications – First, this paper proposes a framework of strategy maps for NRIs to transfer the strategy into clear and concrete action initiatives, and the corresponding performance evaluation indicators. Also, this paper gives a case study of a research institute in the field of physics to derive KPIs based on its strategy maps, which can show the effectiveness of this approach. But this institute conducts mainly the basic research, and there are other NRIs with different types of research, such as applied research, which have different characteristics with the NRI in the case study.

Originality/value – The authors propose the specific strategy maps for NRIs and a new method to set targets for KPIs. Further, the example of a national research institute is taken to analyze its strategy map and construct a performance measurement indicator system for it, so that the strategies in research

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management can be transferred to specific action initiatives. New ideas are provided for the performance measurement of national research institutes.

Keywords Performance measures, Strategy maps, National research institutes

Paper type Research paper

1. Introduction

Performance management has become much more common in government managed organisations in the past few years as a consequence of two principal factors:

(1) increased demand for accountability by governing bodies, press and the general public, and

(2) a growing commitment by organisations to focus on results to improve performance (Poister, 2003).

Marr and Creelman (2011) define performance management as "the execution of the organization mission through the coordinated effort of others". The mission, of course, is defined from the strategy that sets down the organisational goals and objectives. During the past two decades, the public sector has attempted to remove waste, bureaucracy and an inwards focus from the public sector bodies in question. The recent economic downturn in Western economies has caused public sector organisations to be pressured into using their scarce resources not only much more efficiently but also with greater effectiveness (Marr and Creelman, 2011).

With the increasing investment in science and technology since the 1980s, the People's Republic of China Government and the public have expected increasingly high-quality scientific research from scientists, which should benefit the nation intellectually and economically. During the same period, national research institutes (NRIs) in China have sought to continuously improve the quality and the efficiency of their research and to display their research outputs to the government and the public. The assessment of scientific research and performance has become an important tool of public administration to aid that process.

Jaffe (2011) points out that it's difficult to evaluate and measure outcomes and outputs in the public sector like research institutions. So, it is necessary to understand that outputs represent what a programme actually does, whereas outcomes are the results (benefits) it produces (Poister, 2003). ISO 21500:2012 (2012) defined that the outputs are deliverables, and outcomes are the effects of using these deliverables. According to Marr and Creelman (2011), there exists the danger that public sector organisations concentrate on measures that relate to outputs only because they are easy to measure rather than on outcomes, which are the goals to which an organisation aspires and more problematical to measure, as it may be the case that several outputs contribute to a single outcome. However, if the focus is on outcomes, then the potential for improved efficiency, collaboration and performance improvement is increased, as the work activities (outputs) are aligned to achieving those goals. What is being stated is that the public sector organisation's focus on outputs should be congruent with and provide support to the desired outcomes. However, research by Marr and Creelman (2011) showed that most organisations focussed mainly on outputs, and this was attributed to the lack of a clearly mapped strategy. Additionally, the reason attributed by Marr to public sector organisations concentrating so much on output-based metrics is that governments have imposed rigidly set performance targets, and these become the priority for the bodies required to deliver the range of services.

There has been a general discussion about measures and indicators, and the issues discussed also relate to metrics applied to scientific research. Meyer (2002, p. 30) proposed seven purposes of performance measures. He suggests that large and complex organisations require more from their measures than do smaller ones. The latter may only need measures which "look ahead, look back, motivate and compensate people", whereas more complicated organisations require measures that "roll up from the bottom to the top of the organisation, to cascade down from top to bottom, and to facilitate performance comparisons across business and functional units". Antonelli (2003) argues that economic growth in today's knowledge-based economy is based on innovative capacity fuelled by knowledge and technologies – in other words, high-quality research activity. Our research institutes meet that need and often have a number of objectives they are required/wish to achieve. However, there are some specific difficulties that arise in the scientific field. Geisler (2000) defined metrics for evaluating scientific work as a system of measurement that includes the following:

- the objective being measured;
- the units to be measured; and
- the value of the units.

He then refines this definition of metrics to describe what object was being measured, the means by which the object was measured and then provided a reason for why it was being measured – in other words, the value of the product. He makes, by way of example, the connection between the number of peer-reviewed journals with the performance and, therefore, value of scientists. The difficulty here, as Geisler concedes, is that the metric, which has been derived from an analysis of the theory of measurement (e.g. the number of peer-reviewed journals, bibliometric indicators and patent award indicators), is a one-dimensional quantitative assessment when what is supposed to be measured (the value of the scientist) is much more of a qualitative assessment and ought to include the scientist's overall contribution to the scientific programme.

Antonelli (2003) argues that economic growth in today's knowledge-based economy is based on innovative capacity fuelled by knowledge and technologies – in other words, high-quality research activity. Our research institutes meet that need and often have a number of objectives they are required/wish to achieve. Keeney and Gregory (2005) studied how to select measures effectively to determine whether bodies that operate in such an environment are meeting their targets (i.e. assessment indicators). Roper *et al.* (2004) discussed the indicators for the pre-assessment of public R&D funding, based on the beneficial outcomes that increased knowledge provides to society. Moreover, soft systems methodology can be used to analyse systematically the operation of research institutions to build a relatively more complete and reasonable set of evaluation indicators based on the "3E" theory (efficacy, efficiency, effectiveness [Mingers *et al.*, 2007, 2009]). However, even if we can determine a causal model founded on acceptable theories, the concept of performance has no inherent value unless the information produced from it is used for decision-making purposes to assist with executing the organisational strategy. Unfortunately, the links between performance evaluation systems and organisational strategies were ignored in these research works, and this represented a very significant weakness in their utility for us. Although Zhang *et al.* (2011) has discussed the conceptual template of strategy maps for NRIs, they failed to propose the approach to set targets for performance indicators.

The discussion above sets the context for the rest of the paper, which sets out to help research managers design the performance management process and select measures and indicators, which relate to the strategies of their organisations directly. In this paper, we will propose the specific strategy maps for NRIs, so that the managers can describe the strategies of their organisations more clearly, accurately and logically. Also, we will propose a new method to set targets for key performance indicators (KPIs), which is named "Forecasting-Objective Achievement System (FOAS)". Also, we will take the example of an NRI to analyse its strategy map and construct a performance measurement indicator system for it, so that the strategies in research management can be transferred to specific action initiatives. It provides new ideas for the performance measurement of NRIs.

The remainder of the paper is organised as follows: Section 2 briefly reviews the studies on performance measurement, especially on balanced scorecard (BSC) and strategy maps (our framework of choice). Section 3 proposes the strategy maps for NRIs. Section 4 proposes a new method of target-setting for performance indicators. Section 5 provides an illustrative example to demonstrate the potential applications of strategy maps in performance measurement system of NRIs. Section 6 concludes this paper.

2. An overview of the studies on performance measurement

The dictionary definition of "performance" emphasises the situation of the organisation at present or in the past, but not in the future. By this definition, "performance" is observable and measurable – theoretically at least. However, economic "performance" emphasises anticipated results in the future, which may be an estimation based on past or present behaviours of the organisation and needs to be shown over a defined period of time. These two definitions reflect the two main stages of the theoretical development of performance measurement (Meyer, 2002).

Meyer (2002, p. 30) proposed seven purposes of performance measures. He suggests that large and complex organisations require more from their measures than do smaller ones. The latter may only need measures which "look ahead, look back, motivate and compensate people", whereas more complicated organisations require measures that "roll up from the bottom to the top of the organisation, to cascade down from top to bottom, and to facilitate performance comparisons across business and functional units".

Understanding the nature of measures is inherently important when discussing performance management systems. Traditional financial measures were designed to compare current and previous periods based on internal standards of performance. They do not provide direct or explicit information on such topics as quality, customer satisfaction or staff problems that can all impact on long-term profitability. However, accounting measures are relatively easy to collect, quantitative in nature and demanded by many governance requirements around the globe. Working in mission-based organisations (more usually public sector and charitable organisations), importance is often placed on characteristics such as organisational collaboration. This is something that financial measures cannot capture. Moreover, financial data are usually abstracted at higher levels to such an extent that the workforce is unable to make individual use of that information, and it may be of limited value to those for whom it is intended – senior management (Maisel, 1992; Kaplan and Norton, 1996a, 1996b, 2008; Niven, 2003, 2006; Marr, 2006). Despite the limitations described above, financial metrics remain an essential part of the performance management systems, particularly in public and not-for-profit sectors where there is a need to balance effectiveness and efficiency with aspirational outcomes/goals. Pursuing goals with no regard to the financial ramifications of decisions will be ultimately damaging if it becomes clear that an organisation is unable to manage its resources properly (Marr, 2006).

Stakeholders are looking for the organisation to achieve its mission (which in the public/not-for-profit sector will not be centred on finances/profitability); therefore, non-financial measures of performance become critical. These then become leading indicators of future performance and important components of strategic performance management. On the other hand, organisations do need to accept that there are limitations of measurement and that often proxy measurements are used. However, in the absence of anything better, they can empower people to become accountable for strategic performance.

Management guru Charles Handy has observed, "Measuring more is easy, measuring better is hard", and Marshall Meyer adds that "measuring performance is difficult and the choice of performance measures is often arbitrary, since it is difficult to prove that any one measure is better than others" (Meyer, 2002). It is hard, if not impossible, to capture the whole story in one measure. Pike and Roos (Neely, 2007) when discussing the validity of measurement frameworks, cite Ittner and Larcker (2003) who suggested that there are five mistakes commonly made in business measurement systems when designing non-financial measures:

(1) the measures do not relate to the strategy;
(2) there are no causal links between the measure and the activity being measured;
(3) incorrect performance standards and targets are set;
(4) incorrect measurement takes place; and
(5) too many measures are used, which serves to confuse the picture rather than assisting with strategic management.

During what we shall call Stage I (1880s-1980s), the main performance measurement indicators were financial and productivity-related in nature, such as profit, return on investment, output per capita, profit margin, units produced per hour, units produced per employee and so on. However, these indicators were not only *ex-post*, but they could not reflect the internal operations, long-term development and human aspects of performance. Stage II (late 1980s onwards) occurred as global competition became more intensified, and organisational strategies, technologies and philosophies for new production management were being applied and developed. The notion of cause and effect linkages between objectives arose during the late1980s and early 1990s, and some frameworks were developed to assist with performance measurement, but it was not until Kaplan and Norton (1992) proposed the BSC that frameworks of this nature became popular. The proponents of the BSC claimed that it had an immediate revolutionary impact on performance measurement theories. Compared with the traditional theories of performance measurement, the innovative ideas of the BSC were mainly reflected in two "balances". First, organisational performance measurement should have a balance between the short-term (current) and the long-term (future) performance. Second, performance measurement should achieve the balance between the tangible and intangible assets (knowledge) of the organisation.

In recent years, the BSC had become a well-established and popular practical technique (Silk, 1998; Marr, 2006; Rigby, 2005, 2007). Our research concluded that it was easily comprehensible, and it had a copious explanatory literature, and numerous illustrative cases were available. There was also advocacy of its applicability to the public sector (Niven, 2003, 2006; Lawrie and Cobbald, 2004). Although initially presented as a performance management tool (Kaplan and Norton, 1992), its development led to its advocacy as a basis for strategy development and implementation (Kaplan and Norton, 1996a, 1996b, 2001a, 2001b). In part, its capability in this respect lay in communicating strategic objectives in a meaningful way throughout an organisation by using cascades of BSCs (Kaplan and Norton, 1996a, 1996b). The third generation form had firmly established it within the strategy process (Lawrie and Cobbald, 2004). Its use in practice was well-supported by software availability.

A distinguishing feature of the BSC was the cause/effect structure that linked the perspectives together (Kaplan and Norton, 1996a, 1996b). This meant a lead/lag relationship between measures, and this could engender management pro-activity to take corrective action when lead indicators deteriorated. The possibility of using it to motivate was also present through the capacity to set targets for the selected measures. Although all of these advantages were persuasive in the decision to use the BSC, the research team were also aware of some drawbacks that had been associated with it. The top-down implementation emphasis associated with it (Nørreklit, 2000; Norreklit *et al.*, 2008) may not sit well with the culture of scientific staff. The need to heed the warning that cause/effect relationships could be logical in nature rather than causal in the original BSC was noted as a factor to be considered in design (Nørreklit, 2000), and some scepticism was felt over the representation of its ease of use by advocates, for example, in its comparison with a pilot or ship captain using mechanical instrumentation to readily gain their destination (Nørreklit, 2003; Nørreklit *et al.*, 2007). The principal reason for this latter objection was that it implied a more operational role for the BSC rather than a strategic one for which it was intended. If operational visualisations were required, then dashboards may be more appropriate than scorecards (Cokins, 2009).

The original BSC (Kaplan and Norton, 1992) was a strategy execution framework which identified and integrated four different perspectives in terms of looking at performance (financial, customers, internal business processes, innovation and learning). Clearly, these perspectives are much more suited to a profit-motivated organisation than to a public sector research institute. Niven (2003), amongst others, understood that the public sector had similar needs to those of the private sector when it came to executing their strategies. The original version of the BSC had some deficiencies relating to the public sector, and Kaplan and Norton's BSC would need to be adapted if it was to better suit government and non-profit organisations; therefore, he proposed a public sector scorecard. However, what Niven (2003) accomplished was merely to revolve the scorecard around its axis, so that the customer perspective rather than the financial perspective connected directly with the organisational mission statement; he maintained the same labels for each of the four perspectives. Niven (2003) had, despite the rather limited adaptation, identified that the scorecard became a much more useful framework, as it provided scope for customisation to the requirements of the adopting organisation and his work reinforced the views of others in this respect (Kaplan and Norton, 1996a, 1996b; Ewing, 1996; Dittmann *et al.*, 1997). A further attraction was the clarity of structure which the complementary technique of strategy mapping could bring to the process of strategy formulation and presentation (Kaplan and Norton, 2004, 2008). During their research Macnab *et al.* (2010) also proposed that the perspective labels should be adapted to meet the specific needs of the organisation (Royal Botanic Garden Edinburg [RBGE]) employing the scorecard rather than attempting to maintain the generic labels posited by Kaplan and Norton (1992), and indeed, they proposed subsequently that a fifth perspective be included in public sector scorecards to represent the needs of the principal external stakeholder(s) to ensure a better alignment of purpose.

In the next section, we will show how to build the template of strategy maps and corresponding performance indicators of NRIs using the idea enlightened by BSC.

3. Strategy maps of NRIs

In this section, we will propose a general template of strategy maps for NRIs based on the basic rules for research activities. We can see that Kaplan and Norton's four perspectives are mainly based on the characteristics of commercial enterprises, so they does not complement the research activity of NRIs in many ways, which have different social positions. NRIs must meet the strategic goals which include carrying out directed basic researches, developing strategic high-tech innovations, devising systems integrations and major innovations related to the economic or social welfare and sustainable development. Finally, they provide public goods and social services for the country and Chinese society. Consequently, activities of NRIs need to be based on the national strategy set down by the government. Most of their goods and services cannot be priced directly through the market mechanism, like those of commercial enterprises, and for which organisational performance can be measured through profits (Hanley and Spash, 1993; Copeland and Fixler, 2009). According to Bozeman *et al.* (2005), public scientific endeavour can be measured against a number of criteria including the following:

- objectives described in governmental policies;
- goals articulated in policy statements;
- government agencies goals set down in their strategies; and
- public budgeting statements.

Such measurements can be triangulated from opinion polls, policy statements by relevant non-governmental organisations and other public interest groups. Moreover, the principal funder and customers of NRIs usually overlap. On the one hand, the funding of NRIs is mainly from the central and local government's direct financial grants or project funding, and therefore, the national government and the public can be seen as the principal funders for NRIs. On the other hand, NRIs hope that their research can improve the international competitiveness of industries for the country, promote economic growth and increase welfare for citizens. Therefore, national government and the public can also be seen as the ultimate customers of NRIs.

Based on the above considerations, we will construct the template of Strategy Maps for NRIs from the perspectives of "clients", "internal operations", "learning and growth" and "finance" as follows.

3.1 Clients (the country and the society) perspective

This perspective sets down the objectives which create long-term values for the country and society and are to be met by the NRIs. In effect, this perspective represents the strategic outcomes or intermediate outcomes (Figure 1). These outcomes are achieved collectively by the endeavours of the various NRIs, which, in turn, have crafted their own mission statements supported by vision statements and strategic objectives pertinent to the individual NRI. For example, in describing how to create long-term values for the country, the Chinese Academy of Sciences (CAS) in its 2002 guidelines states:

> Targeting the national strategic needs and world frontiers of science, striving to accomplish world-class science and continuously making fundamental, strategic and foresighted contributions to China's economic sustainability, national security and social development, through strengthening original scientific innovation, innovation of key technologies and system integration.

In general, NRIs' creation of long-term values for the country and the society is derived mainly through the following methods:

- First, target national strategic needs and complete the major research tasks related to the people's livelihood and national security. For example, Professor Longping Yuan's research on hybrid rice, "Two bombs and one satellite" project

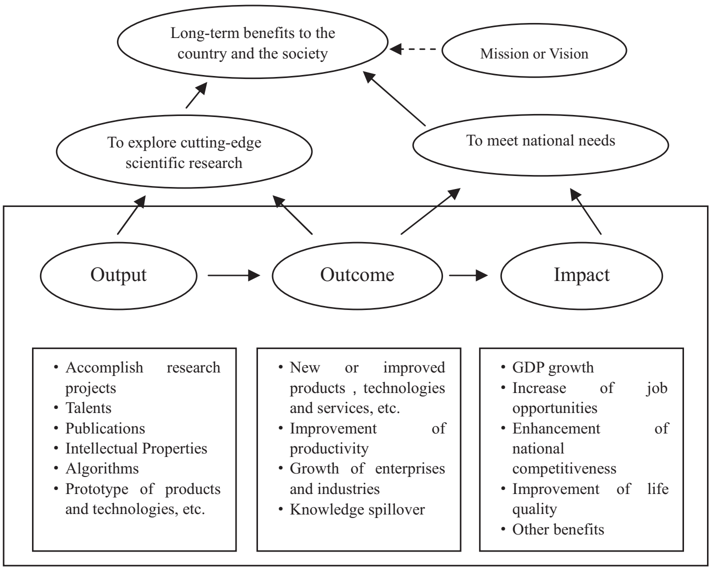

Figure 1.
NRIs' strategy map from the client perspective (state and society)

in China in the 1950s and 1960s, the current spacecraft "Shenzhou" project, "Chang E" lunar exploration project and some other major military tasks.

- Second, explore the cutting-edge sciences and make great primitive (or breakthrough) innovations in scientific research. Primitive innovations will often bring a huge explosion of industrial productivity. For example, the French scientist Phil and German scientist Krupp were awarded the 2007 Nobel Prize in Physics because of their study on the effect of "giant magnetoresistance". When the award of the Prize in Physics was announced, the Nobel Prize Committee said that this was a "discovery led by curiosity". But its application eventually led to the technological revolution of the information industry for the storage medium, which enhanced the hard drive capacity for computers from dozens of Megabytes to hundreds of Gigabytes (1G is equal to 1024M).

The contributions of NRIs for the country and the society include the followings:

- Direct outputs (Output), i.e. the immediate short-term results that the research institutions have conducted in a short-term, such as scientific papers and patents. These outputs are deliverables of NRIs to their clients.
- The indirect effects (Outcome), which are the benefits to the industry through the industrialisation of the research results or other means of knowledge spillover, such as new products or new technologies and the growth of the companies or the industries. The outcomes are the effects of using the direct outputs mentioned above.
- Long-term impact (Impact), i.e. the ultimate long-term benefits to the country and the society brought by the research, such as the growth of gross domestic product, the national competitiveness enhancement and the improvement of life quality (Figure 1).

3.2 Internal operations perspective

This perspective aims to analyse how the managers can strengthen their internal management and improve critical internal processes to achieve the organisational missions and visions, and thus meet the needs of the country and society. For NRIs, their internal business processes contain the following four parts.

3.2.1 Innovative planning process. With a clearance of the missions of their organisations, the research managers can discuss and adjust the layout of the study subjects with internal and external peer experts to identify the major opportunities for innovation. Merton (1957) found that the priority for a scientific discovery is different from a private property rights. This particular system leads to a "winner takes all" competition for scientific research. Therefore, how to discover major scientific issues and how to access to the priority of scientific discovery are very important for researchers. In addition, at certain stages of scientific development, scientific results are often faced with huge industrial opportunities. At the present stage that the corporations' R&D capabilities are still weak in China, research managers need to timely identify the opportunities for major innovations in the research, and organise scientific research teams to focus on them.

3.2.2 Research and development process. Upon the completion of the future orientations and the layouts of disciplines of NRIs, the managers need to further organise their internal research teams to choose the projects and complete the applications, according to the orientations and academic layouts. When the applications are approved, the researchers should also be aware of the projects schedule and the risk management in addition to the scientific research activities.

3.2.3 Graduate training process. Because the flow of scientific and technological professionals is an important way of knowledge spillover, the training of high-quality professionals is also an important output of the research activities of NRIs[1]. NRIs should do well on graduate admission, participation in the research projects and instruction on thesis writing, etc., to improve the quality of graduate training.

3.2.4 Social relationship process. In addition to providing public goods, NRIs should also be actively involved in various social and academic activities to expand their academic and social influences. At present, some researches on the scientific map have shown that the prestigious research institutions in the international academic community are often located at the centres of the academic exchange network, which means that the academic social network will have a positive external effect on scientific research (Bornmann *et al.*, 2011). In addition, NRIs also need to provide some public services for the society, such as the activities to popularise scientific knowledge and provide advisory reports.

Finally, NRIs can directly solve technical problems or develop new products for the enterprises and create direct economic benefits through the cooperation with businesses (Figure 2).

3.3 Learning and growth perspective

This perspective is to analyse how to make appropriate strategic adjustments for the internal resources of the organisation (i.e. organisational capital, human capital and research platform) to support NRIs' excellent internal processes. The specific contents are as follows:

3.3.1 Organisational capital. Currently, research teams are playing more and more important roles in scientific research. Stephan and Levin (1992) argued that the reason research teams are becoming more important is mainly due to specialisation of modern sciences. Significant achievements made by scientists depend not only on their levels of efforts but also on their cognitive resources (i.e. knowledge bases). Researchers in research teams can very conveniently get access to other members' cognitive resources as well as their own. Therefore, the team research activities may be more productive than the individual. NRIs' organisational capital includes intellectual, relational and

IPP	RDP	GTP	SRP
• Identify major research opportunities; • Identify innovation opportunities • Adjustment of disciplines layout	• Projects applications; • R&D activities; • Schedule & Risk management	• Students recruiments • Teaching • Taking part in research projects • Training quality	• Research cooperation • Technology transfer • Communication with other research organizations • Popularizing scientific knowledge

Figure 2.
NRIs' strategic map from the internal operation perspective

structural capital. Intellectual capital refers to a long-term accumulation of implicit and explicit knowledge and the update rate of knowledge for the research team; relational capital refers to internal and external relations of the team, including the organisational structures and patterns, system of rules for encouraging academic exchange and co-operation and the manager's leadership; structural capital refers to the cooperation among various research teams within the organisation (i.e. the innovation culture). A good innovation culture can help in forming a tolerant and profound academic atmosphere within the organisation.

3.3.2 S&T human capital. The human capital of research institutions includes the talent of research leaders, the knowledge and skills of researchers and the training, the incentive and other organisational measures for the researchers. The range of productivity among scientists implies that the innovation capability can be determined by the number of outstanding scientists in the research organisation. In the bibliometric studies on physics journals of the nineteenth century, Lotka (1926) was the first to discover that the distribution of the communities of scientists in the journals was highly skewed, i.e. most of the papers were published by a minority of the scientists. Some scholars found the same phenomenon in other fields of sciences (Fox, 1983). Initially, some scholars tended to attach the skewed distribution to the differences in the characteristics of the scientists, such as personal ability and motivation. However, social scientists found that the unbalance of the distribution will increase with ages of the scientists. Therefore, they proposed that the uneven distribution of scientific research is an inevitable consequence of the "Matthew effect" or "accumulated advantage" (Merton, 1968; Cole and Cole, 1967, 1973; Cole, 1979), i.e. because of the feedback and strengthening process from the society, a productive scientist will be more productive in the future. Another interesting discovery in the sociology of science is that the productivity of a scientist is highly relevant to his/her life cycle. Because the life is limited, human capital ultimately decreases over time. So the scientist's productivity will increase with the age at first, and then decrease (Levin and Stephan, 1991; Gonzalez-Brambila and Veloso, 2007).

3.3.3 Research platform. The research platform includes scientific instruments and equipments, field stations, scientific literatures, museum specimens, germplasm network, resource library, etc. For example, the research equipments are playing a more and more important role in scientific activities. It implies an increasingly stronger mutual promotion between science and technology. First, the development of science makes it possible for the emergence of technological revolution; second, technological progress brings more and more inventions of new instruments, which greatly promote the development of the science itself. For example, in the twentieth century, with the inventions of radio telescopes and electron microscopes, the scientists can observe the macro-phenomena of the universe, the micro-phenomena of the molecular and atomic structures more precisely. Since the introduction of high-class accelerator in the particle physics, scientists can directly see the inside world of an atom. Stephan and Levin (1992) has expressed such a sense of humour in their metaphor for the impact of research equipments in research activities:

> In the present scientific world, the birds who can catch insects are not necessarily the smartest or the most diligent, but usually those who have been equipped with the most efficient tools (Figure 3).

3.3.4 Financial perspective. This perspective is a major analysis for the problems whether and how a research institution can obtain sufficient funding to support its research activities. At present, NRIs in China have four main sources of funding:

(1) first, the direct funding from the country to NRIs, including research staff salaries, operating expenses;
(2) second, the NRIs carry out research activity by applying for the projects from national funding organisations, such as the Projects of 973 supported by the Ministry of Science and Technology and the projects from the National Natural Science Foundation (NSFC);
(3) third, NRIs can get access to cross-funded projects from enterprises, with a cooperation of industry, education and research; and
(4) finally, the research products can be changed into the income of the institutes through the licensing and transferring of the pattern, technical services, etc.

Besides increasing funding and income, managers of NRIs can also improve the internal efficiency of scientific research, to guarantee the smooth operation of research activities. For example, enhance the sharing of scientific instruments. In addition, to improve the efficiency of research activities is a basic requirement of the country and the society for NRIs (Figure 4).

4. Targets setting for KPIs

One of the most commonly used methods for target-setting for KPIs is negotiation between managers and performers, which is a feasible way for a single NRI. In the negotiation process, the manager of NRI is intended to set relatively low targets for KPIs, which is easy to achieve. On the contrary, the decision-maker (DM) from headquarters wants NRI to try its best to increase the outputs using limited resources and to achieve targets as high as possible. The final targets depend on their negotiating skills and cannot reflect the NRI's best efforts. Because of the complexity of research activities, how to set suitable targets for KPIs is also left as a problem.

In this section, a new method to set targets for KPIs is proposed, which is named "Forecasting-Objective Achievement System (FOAS)". There are three assumptions as follows:

- *Assumption 1*. If the value of a certain KPI is higher, then the performance on this KPI is better.
- *Assumption 2*. Whether or not the objectives of KPIs have been achieved can affect the NRIs' performance.
- *Assumption 3*. Through target-setting for KPIs, DM can know the NRIs' development status and productivity in the future, so that can make better strategy and layout.

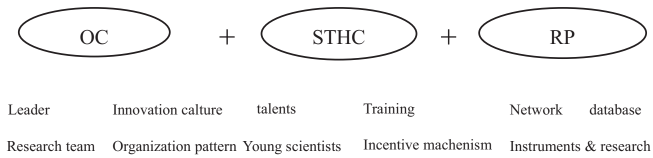

Figure 3.
NRI's strategy map from learning and growth perspective

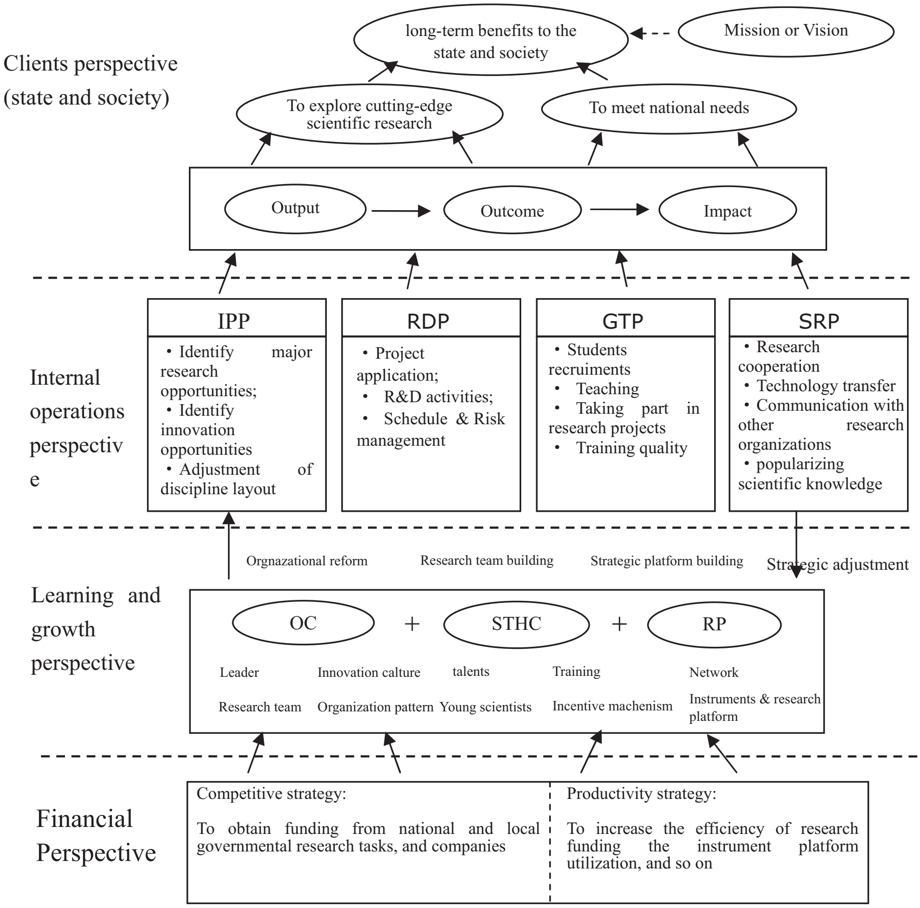

Figure 4. Template of NRIs' strategy maps

Based on the above assumptions, we give the details of FOAS as follows. First, we make the following notation:

- Q*: The target set by the headquarters for certain KPI;
- Q: The real output of certain KPI;
- F: The forecasting of NRI's manager for certain KPI; and
- B: The forecasting-objective achievement for certain KPI;

The forecasting-objective achievement for certain KPI can be obtained through following equations:

$$\text{If, } Q > F, \text{ then } B = (\alpha \times F + \beta \times (Q - F))/(\alpha \times Q^*) \tag{1}$$

$$\text{If, } Q \leq F, \text{ then } B = (\alpha \times F - (\alpha + \beta) \times (F - Q))/(\alpha \times Q^*) \tag{2}$$

where α, β are regulatory factors, which can regulate the intensity of incentives. The regulatory factors can be adjusted according to different institutes or requirements.

To understand this method clearly, we let $\alpha = 0.3$, $\beta = 0.2$, then we have:

$$\text{If, } Q > F, \text{ then } B = (0.3 \times F + 0.2 \times (Q - F))/(0.3 \times Q^*) \tag{3}$$

$$\text{If, } Q \leq F, \text{ then } B = (0.3 \times F - 0.5 \times (F - Q))/(0.3 \times Q^*) \tag{4}$$

See Table I for the details.

From Table I, we know that in each row, the element on diagonal is the maximum, which can show that the forecasting-objective achievement will achieve maximum if NRI's manager can forecast the output of certain KPI precisely. Also, in each column, the forecasting-objective achievement increases with the increase of real output, which can reflect that if the value of certain KPI is higher, then the performance on this KPI is better. Furthermore, whether or not the objectives of KPIs have been achieved also is taken into account in FOAS.

Here we give the detailed steps of "Forecasting-Objective Achievement System (FOAS)" as follows:

- *Step 1*. According to the development strategy and layout, the headquarters in charge of NRI sets the targets for KPIs of NRI at the beginning of a year.
- *Step 2*. The headquarters make the NRI understand the mechanism of "Forecasting-Objective Achievement System (FOAS)".
- *Step 3*. The manager of NRI provides forecasting on each KPI according to the target set by headquarters.
- *Step 4*. The headquarters formulate its working plan to provide necessary supports for NRI according to the forecasting of NRI of the manager.
- *Step 5*. The headquarters calculate the forecasting-objective achievement according to the real output, targets and forecasting by NRI manager at the end of the year.
- *Step 6*. The headquarters make the development plan and layout for the next year at the year-end.
- *Step 7*. Go to Step 1.

5. A case study

An NRI (which will be the institution in the discussion throughout this section), mainly for the basic research and the applied basic research on condensed matter physics, has

Table I.
Illustrative data for forecasting-objective achievement ($\alpha = 0.3, \beta = 0.2$)

Achievement		F/Q* (Forecasting/objective)				
Q/Q* (Real output/objective)		0.5 (%)	0.8 (%)	1 (%)	1.2 (%)	1.5 (%)
	0.5	50.00	30.00	16.67	3.33	–
	0.8	70.00	80.00	66.67	53.33	33.33
	1	83.33	93.33	100.00	86.67	66.67
	1.2	96.67	106.67	113.33	120.00	100.00
	1.5	116.70	126.67	133.33	140.00	150.00

more than 400 employees in total and more than 300 in innovation positions until 2009, including 14 academicians, 114 researchers and more than 640 graduate students. About 93 per cent of its funding comes from the central budget. Based on full discussions and communications with the managers and the researchers, we will analyse its strategy maps and propose a performance evaluation system. Through the study of this case, we will see how the strategy maps can become an efficient tool for a research institution to develop and implement its strategy and effectively fulfil the performance measurement.

5.1 Strategy maps and KPIs

From the client perspective, exploring the cutting-edge scientific research and meeting the long-term strategic requirement of the country are the goals of this institution.

- *The goal for cutting-edge sciences*: Get original achievements in the basic research and create new growth points and directions at the forefront of sciences which are worldwide concerned.
- *The goal for national requirements*: Enhance the scientific and technological innovations, achieve sustainable economic and social developments for our country and make an important role in building our innovative country.

On clean energy, optoelectronic information, the new functional materials, etc., the institution will have a positive commitment in undertaking and fulfilling national major projects, with technology products which have critical applications for the strategic requirements of the country. For the industrialisation, major breakthroughs will also be expected on clean energy, optoelectronic information, nanotechnology, new functional materials, etc.

5.1.1 Internal operations perspective. To meet these strategic goals, the key processes are proposed by the institution.

- *The layout of strategic goal setting and academic adjustment*: Strengthen the multidisciplinary integration of condensed matter with optical physics, atomic and molecular physics, plasma physics, etc., and form such a pattern in the systematic cutting-edge research for the material science that condensed matter stays in the centre, surrounded by energy, material, information and other multidisciplinary sciences, all closely related to each other.
- *Research management*: Choose the topics and subjects on the target and the layout, complete the selection and application of the projects, at the same time improve the regulatory capacity for the funding at the institute level.
- *Training excellent researchers*: Nourish several distinguished scientists who will greatly affect the development of physics science, train more than a dozen of world-famous research leaders, foster a first-class innovative research team, which has a rational size and structure, the ability and the challenging spirits capable for the cutting-edge research and sustainable original products. It will represent the best research ability of our country for condensed matter and related sciences and a great influence in the world community of science and technology.
- *Excellent quality of the students and the mechanisms*: Strengthen the research-oriented principles for graduate students in the entire process of the graduate admission and education. Further strengthen and improve the supervisor

accountability, strengthen the guidance for the construction and management of the teaching body, reform and improve the system of graduate scholarships to further mobilise and inspire students' enthusiasm.

- *International and domestic academic exchanges*: Encourage academic exchanges with foreign counterparts to further broaden the academic perspectives of the researchers.

5.1.2 Learning and growth perspective. To support the effective operation of the key internal processes, the institution decides adjustments of their resources and organisational structure in the following aspects:

- For the organisational capital in research, the institution needs to establish a rational and effective organisational structure and improve the leadership, strengthen the construction of the system and the culture for innovation and build good research teams.
- For the human capital in research, train or introduce research leaders, build the team of talents, emphasis the preparation of the reserve forces for the research and establish special funding for the talent to increase the competitiveness of the human capital in research.
- *Research platform*: Build a modern comprehensive large-scale platform and a world-class research base for national public study of condensed matter physics, as well as a good platform for scientific information and research equipments.

5.1.3 Financial perspective. The institution needs to undertake the research tasks of the country and local governments, undertake corporate research projects from enterprises, increase its support for self-developed world-class sophisticated large-scale equipments and

Modules	Objectives	Measurement indicators
Meet the requirements of the country and the society	To enhance the capacity of the national S&T innovation, to achieve sustainable economic and social development and to build an innovative country	Invention patent applications, licensings and transfers Number of the consultation reports with substantial impacts Economic benefits of the industrialisation of research outcomes Social benefits
Explore the cutting-edge scientific research	Get original research products, find new growth points and new directions on the forefront of the world of sciences, which are the subjects of attentions for international counterparts in several basic research areas	Number of papers on the journals with high impact factors Papers with high number of citations Invited reports on international academic conferences series Domestic and international academic awards

Note: S&T = science and technology

Table II.
Relevant objectives and measurement indicators from client perspective

increase the research funding and the efficiency in the utilisation of the instruments platform.

Based on the above analysis, we propose the strategy maps of this institution. As we can see from this case study, any different type of institutions can have the strategic map analysis with a similar logic, which can help step by step sorting out its mission and strategic goal, as well as a series of specific programmes for the actions to fulfil its strategic objectives. On this basis, we can construct its performance measurement indicators for each component of the objectives and programmes in the strategy maps (Tables II-V).

5.2 Target-setting for KPIs

In this section, we take the indicator "Number of Papers on the journals with high impact factors" to demonstrate how to set targets for NRI's KPIs. This NRI produced 583

Modules	Objectives	Measurement indicators
Innovative planning process	Reasonable, clear and feasible strategic goals, which are consistent with the mission of the organisation	Experts review
	Rational, scientific and forward-looking subject layout	Experts review
Research and development process	Effective R&D project management	Number of approved project applications Success rate of project applications Ratio of the projects completed on time Project funding per capita
Graduate training process	Excellent quality of the students and the mechanism	Proportion of the graduates whose theses are selected as the national 100 best theses Proportion of the excellence award winners Graduates over the years Disciplines building (see the result of disciplinary assessment) Proportion of graduation in all the graduates Number of students in international co-operative training
Social relationship process	Good academic exchange and cooperation	Number of visiting scholars whose visiting period was longer than one week Hosted/sponsored international conference series Projects and outcomes of international co-operations Various academic symposium

Table III. Relevant objectives and measurement indicators from internal operation perspective

Modules	Objectives	Measurement indicators
Organisational capital	Rational and effective organisational structure (consistent with the strategic objectives)	Experts review
	Improvement of leadership skills	Experts review
	System and the building of an innovative culture	Experts review
	Good research teams	Number of research teams selected as NSFC scientific innovation team
S&T human capital	Training or introduction of scientific talents	Actual effects (such as internationalisation)
	Research team building	Proportion of the talents in the researchers
	Development of scientific back-up personnel	Post holding in international academic journals and academic organisations
		International competitiveness of the talents
		The mechanism of introducing and training young researchers
Research platform	Good research information platform	Satisfaction degree of the researchers on the information systems
	Good research equipments	Satisfaction degree of the researchers on the utilisation of scientific instruments
		Integrity of the scientific instruments and the technology platform
		Features of the scientific instruments and the technology platform

Table IV.
Relevant objectives and measurement indicators from learning and growth perspective

Modules	Objectives	Measurement indicators
Competitive strategy	Adequate research funding	Funding for research projects from national and local governments
		Funding for research projects from enterprises
		Ratio of external funding to direct governmental funding
		Funding per capita
Productivity strategy	Good mechanism for sharing the research platform	Utilisation of scientific instruments and equipments
		Sharing of scientific instruments and equipments
	Good efficiency in the utilisation of the funds	Expenditure of funds

Table V.
Relevant objectives and measurement indicators from financial perspective

high-quality papers last year and the headquarters plan to make a growth of 20 per cent and set the target of this year of this indicator as 700. The NRI's manager's different forecasting on this indicator and the different real output can obtain different achievements. See Table VI for the details ($\alpha = 0.3, \beta = 0.2$).

From Table VI, we can see that if the (target, forecasting, real output) is (700, 600, 600), the forecasting-objective achievement is B = 85.71 per cent. Similarly, if (target, forecasting, real output) is (700, 700, 700), the forecasting-objective achievement is B = 100.00 per cent.

Results indicate that these KPIs of the NRI increase significantly, and we can see that the performance is improved when using the strategy maps to derive KPIs and using FOAS to set targets for these indicators, which can show the effectiveness of this new approach.

6. Conclusions and discussions

How to help managers to design the performance measurement indicators has become a hot topic among international and domestic scholars. Existing research generally ignores the logical link between the performance evaluation system and the organisational strategy. We have explored the general rules of the research activity and proposed the strategic map for NRIs, so that the research managers can more clearly, accurately and logically describe the strategy for the organisational development strategy, and build the performance measurement indicators based on it. It allows the managers to transfer the strategy into clear and concrete action initiatives, and the corresponding performance evaluation indicators. Also, this paper proposed a new method for target-setting for performance indicator to drive NRIs do their best to achieve high performance. According to the results of the case study in Section 5, we find that the performance of this NRI on these KPIs derived based on its strategy maps is improved significantly, so that we can see the effectiveness of this new approach, including KPIs derived from its strategy maps and FOAS for target-setting. It provides new ideas of the performance measurement evaluation for NRIs. In addition, we have discussed a national institute as an example, and build its performance evaluation indicators system based on its strategy maps.

There are still some limitations on this new approach. First, this paper proposes a framework of strategy maps for NRIs to transfer the strategy into clear and concrete action initiatives, and the corresponding performance evaluation indicators. Also, this paper gives a case study of a research institute in the field of physics to derive KPIs

Achievement		F (forecasting)				
Q (real output)		600 (%)	700 (%)	800 (%)	900 (%)	1700 (%)
	600	85.71	76.19	66.67	57.14	–
	700	95.24	100.00	90.48	80.95	4.76
	800	104.76	109.52	114.29	104.76	28.57
	900	114.29	119.05	123.81	128.57	52.38
	1700	190.48	195.24	200.00	204.76	242.86

Note: Here the coefficients $\alpha = 0.3, \beta = 0.2$ are selected by DMs to achieve suitable incentive intensity

Table VI. Forecasting-objective achievement with different forecasting and real output based on its strategy maps, which can show the effectiveness of this approach. But this institute conducts mainly the basic research, and there are other NRIs with different types of research, such as applied research, which have different characteristics with the NRI in the case study. Therefore, more real applications are needed to verify the effectiveness of this new framework for the different types NRIs in different fields. Second, this paper proposes FOAS to set targets for KPIs of NRIs, which are derived based on their strategy maps. In fact, this system is very aggressive, and may put much pressure on the directors of these NRIs. Furthermore, because of the special nature of the research activities, there is a time lag between endeavour and outputs (outcomes). In other words, the efforts of NRIs on KPIs may not afford immediate results, so the rationality of setting explicit quantitative targets for KPIs may be discussed further.

Note

1. Note that student training is a very important work for NRIs in China, which is different from the situation in other countries.

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