ABSTRACT

Research and Development (R&D) is needed for many organizations to satisfy the stakeholder needs and to be competitive in the market. The rising cost, resource constraints, and complexities have demanded the performance measurement (PM) of R&D activities. This paper discusses the need of PM to R&D organizations with particular reference to construction organizations. The development of integrated PM systems which capture financial and non-financial performance of the organization, strategically focused R&D performance measures, and various approaches use to measure the R&D performance are presented.

Keywords: Construction Industry, Performance Measurement, Research & Development

BACKGROUND

Rapidly changing customer needs, competitiveness in domestic and international markets, resource and economic constraints have forced the organizations to engage more in Research and Development (R&D) activities and to find solutions to the challenges that they are facing (Cooper, 1998; Kerssens-van Drongelen et al, 2000). The change from cost-led-pricing to price-led-costing has influenced R&D managers to reduce the cost of products with lower risks and shorter development time (Nixon, 1998).

“R&D have become more complex, as they involve many parties and have a wide range of, often interrelated, technological, market and organizational options to choose from under constrained conditions” (Kerssens-van Drongelen et al, 2000, 113). The pace of industrial technological changes is forcing the organizations to create new alliances and to engage in R&D activities to cater the requirements of
stakeholder needs (Rothwell, 1994). Table 1 shows how the R&D activities are changed over the time to suite the varying requirements of the society while safe guarding the organizational needs.

R&D activities require many resources ranging from human to technical, which require proper utilization. In this context, accountability of these resources is being questioned by the management as well as by the shareholders (Wood, 1998; Nixon, 1998). Therefore, a growing interest can be identified in managing, controlling and monitoring of the R&D activities (Bone & Sexton, 2000). In this regard, the use of performance measurement (PM) system benefits R&D organizations by evaluating the successfulness of their activities.

Table 1. Focus of R&D Activities (adopted from Rothwell, 1994)

<table>
<thead>
<tr>
<th>Generation of Innovation</th>
<th>Focus of R&amp;D Activities</th>
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<tr>
<td>First generation (1950s - Mid 1960s)</td>
<td>Technology push innovation</td>
</tr>
<tr>
<td>Second generation (1960s - Early 1970s)</td>
<td>Increase of manufacturing productivity resulted in competition for market share</td>
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<tr>
<td>Third generation (1970s - 1980s)</td>
<td>High inflation and demand saturation and over supply of products</td>
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<tr>
<td>Fourth generation (1980s - 1990s)</td>
<td>Concentration on the core business activities</td>
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<tr>
<td>Fifth generation</td>
<td>R&amp;D is targeted on more efficient product development, quality and non price factors, corporate flexibility and responsiveness, customer satisfaction.</td>
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This paper focused on identifying the importance of PM to R&D activities. First, the paper defines and discusses the advantages of PM in general terms. This will be followed by the development of R&D performance measures and the strategic impact of PM in R&D. The value added to R&D by implementing PM systems is discussed next. Finally the need of PM to construction R&D is discussed.

**WHAT IS PERFORMANCE MEASUREMENT**

Literally, PM is defined as the “process of quantifying the past actions, where measurement is the process of quantification and past actions determines current
Performance” (Neely, 1998, 5). Procurement Executive Association (1998, 5) define PM as a “process of assessing progress toward achieving predetermined goals, including information on the efficiency with which resources are transformed into goods and services (outputs), the quality of those outputs (how well they are delivered to clients and the extent to which clients are satisfied) and outcomes (the results of a programme of activity compared to its intended purpose”). A similar definition has been given by Moxham and Greathanks (2000) who state that PM ensures the attainment of goals and objectives of an organization. Since PM systems encompasses supporting infrastructure, a wider definition has been given by Neely (1998) as the quantification of efficiency and effectiveness of past actions by means of data acquiring, collection, sorting, analyzing, interpreting and disseminating.

PM has been given a prominent place in most of the organizations as it helps to gain the continuous improvements (Martinez, 2005; Baldwin et al., 2001). Further, PM enables the managers to make decisions based on facts rather than on assumptions and faith (Parker, 2000). Thus, PM has become an integral part of planning and controlling of organizations (Barnard, 1962, cited in, Neely, 1999). Cain (2004) identifies PM as the first stage to any improvement process that benefits the end users as well as the organizations.

PM focuses the employee attention and communicates the priority factors of the organization by linking the organizational strategy with the employee’s occupation (Martinez, 2005; Neely et al, 2002; Magretta & Stone, 2002; The Procurement Executives Association, 1998). When the performance measures are aligned with the organizational strategy, they encourage the employee behaviors also to be aligned with the strategy (Neely et al, 2002; Neely, 1999). Further, continuous job reviews of the employees make sure the objectives of the organization are properly met (Martinez, 2005). Neely (1998) identifies seven reasons for PM to be included in the management agenda such as changing nature of work, increasing competition, specific improvement initiatives, national and international quality awards, changing organizational roles, changing external demands, and the power of information technology. According to Martinez (2005), there are eight positive effects from PM:

- focus people’s attention on what is important to the company;
- get business improvement;
- improve customer satisfaction;
- increase productivity;
- align operational performance with strategic objectives;
- improve people satisfaction;
• align people behaviors towards continuous improvement;
• improve company reputation

PM help the organizations to access the way they are progressing towards the goals and objectives, identify the strengths and weaknesses, and to get an idea about the future improvements needed to face the challenges (Amaratunga et al, 2002; Moxham & Greatbanks, 2000). Further, PM identifies gap between the outcomes and the expectations of the organization. This provides feedback for the organization to intervene, improve, revise and re-engineer the business processes (Melnyk et al, 2004). Lower benefits were gained by the organisations, which lack the utilisation of PM systems, and feedback into the improvement of management development programmes (Longenecker & Fink, 2001). Lawson et al (2003) discuss that the use of PM as a management control tool reduces the overhead costs by 25% and increases the organizational sales, profits and improve the return on assets.

The above section briefly discussed the advantages of PM. According to Martinez (2005), the use of complicated and excess performance measures has created negative effects due to the considerable consumption of time, investments and commitment of people. Further, in some occasions the use of PM systems has limited the freedom of managers due to its rigidity (Martinez, 2005). Therefore, it can be argued that, the use of PM within an organisation generate positive and negative impacts. Yet, the solution is not to avoid the use of PM, but to design a system which is user friendly, and which negate the negative impacts by providing more positive impacts. The below section will discuss the development of performance measures within R&D.

DEVELOPMENT OF RESEARCH AND DEVELOPMENT PERFORMANCE MEASURES

Quinn (1960, cited in Kerssens-van Drondelen et al, 2000) was one of the first authors to apply the PM concept to R&D environment by measuring the current R&D work, expected economic value of R&D output against the cost and productivity etc. By 1970s, companies were adopting various mechanisms, mainly output and outcome based performance measures to measure certain aspects of R&D (Kerssens-van Drondelen et al, 2000; Robert, 1994). The performance measures related to R&D used during the earlier days (1970s) mainly focused on three indicators (Robert, 1994):

• strictly technical products (patents, technical publications or citations to technical publications);
• financial benefits that immerge from R&D (profits, sales); and
• judgments about the success of individual R&D projects

Despite the deficiencies of these output and outcome based measures, due to the ease of countability and the lack of alternative measures, their adoption were continued (Schainblatt, 1982). Further, the use of objective measures dominated the R&D PM during the earlier stages (Keller & Holland, 1982; Barnowe, 1975, cited in Moser, 1985). However, Moser (1985, 32) stated “a major question in the use of such objective measures as indices of efficiency is whether they are truly representative of the context of the work settings”.

The use of financial measures as the only criterion of R&D PM has been challenged as they are lagging and not connected with the operational activities (Loch & Tapper, 2002). Accordingly, the need to have non-financial measures for R&D PM arises (Hart, 1993). According to Bremser and Barsky (2004), for the successful attainments of management strategies, aims and objectives, integrated PM systems are required as they capture the changes in financial and non-financial measures. Further, technological advances, customer and profit oriented markets demand R&D to facilitate broad area of activities such as differentiations, time to market, and value for money, service and economic production (Cooper, 1998; Smith & Reinertsen, 1998). Therefore, the need to go beyond the financial measures and to consider customer and shareholder value, business processes, organizational learning and growth were emphasized (Pearson et al, 2000). As a result of that, multiple and integrated performance measures that combine qualitative, quantitative, objective and subjective measures identified as more effective to measure the performance of R&D work (Lin & Chen, 2005; Bremser & Barsky, 2004; Werner & Souder, 1997; Lynch & Cross, 1991).

In addition to the use of financial performance measure for R&D work at the earlier stage, Moser (1985) states that most of the performance evaluations were focused on the individual researchers. Accordingly, the evaluation by supervisor, peers and self-evaluation has been carried out. However, the use of these methods was challenged due to their biasness (Moser, 1985).

This section described the development of PM in R&D work towards more integrated methods. The section below will look into the strategic impact of PM in R&D.

**STRATEGIC IMPACT OF PERFORMANCE MEASUREMENT IN RESEARCH AND DEVELOPMENT WORK**

The product development in most of the industries has been challenged by increased pace of innovation, shortened product life cycle, development of information and communication technologies and globalization (Dahan & Srinivasan, 2000; Soderquist & Nellore, 2000; Tomkovich & Miller, 2000). Companies have
to excel not only in efficiency, but also in quality, flexibility, and innovativeness (McNair & Liebfried, 1992; Wheelwright & Clark, 1992; Bolwijn & Kumpe, 1990). Accordingly, the scope of R&D activities includes a broad array of fields to fulfill the requirements of organisations, customer, and stakeholder needs (Cooper, 1998 and 1995). These demands require a more strategic role for the R&D activities (Edelheit, 2004; Ataide & Stump, 1999; Comstock & Sjolseth, 1999; Khurana & Rosenthal, 1997). Further, Trott (2005, 253) state that over the past years, R&D has been “guided by the aim of its financiers via its business strategy”. Hence, Bremer and Barsky (2004) and Herath and Bremser (2005) identify R&D as a critical determinant of strategic success. This understanding about R&D as a strategic issue has resulted in changes of the management practices within organizations. Accordingly, it has been recognized that R&D cannot be treated in isolation, but has to be aligned and linked with the corporate strategy of the organization (Pearson et al., 2000; Kerssens-van Drongelen & Bilderbeek, 1999; Roberts, 1998; Rogers, 1996; Roussel et al., 1991). How an organization can implement the strategy? According to Bremer and Barsky (2004), “a firm can develop a seemingly brilliant R&D strategy designed to achieve competitive advantage and grow the firm, but implementing strategy is the management challenge”.

In this context, PM of R&D plays a vital role by influencing and helping the organizations to implement their strategies (Bremser & Barsky, 2004; Pearson et al., 2000; Kerssens-van Drongelen et al., 2000; Kerssens-van Drongelen & Bilderbeek, 1999; Brown & Svenson, 1988; Werner & Souder, 1997). The significance of positioning the PM strategically has been well documented in the literature (Kaplan & Norton, 2001; Neely, 1999; Gregory, 1993; Kaplan and Norton 1992; Eccles, 1991; Skinner 1989). PM directs the strategy formulation as well as monitors the implementation of the strategy (Martinez, 2005; Lohman et al, 2004). In the R&D PM literature, it has been identified a shift from lagging financial measures towards forward-looking strategic performance measures (Doukas & Switzer, 1992; Woolridge & Snow, 1990; Chan, et al., 1990). Further, the need of selecting strategic performance measures which focuses on processes, outputs, tangible and intangible assets is being emphasized for PM in R&D (Bremser & Barsky, 2004; Pearson et al., 2000).

The above section highlighted the need of strategically focused PM systems for the R&D. Such PM systems align the processes of the R&D work (R&D, production, marketing and other traditional functional areas) with strategy using lagging (outcome measures) and leading (performance drivers) measures. The section below will discuss the currently available PM applications within the R&D.
THE PERFORMANCE MEASUREMENT METRICS AND FRAMEWORKS USED WITHIN RESEARCH AND DEVELOPMENT WORK

Number of performance measures and frameworks can be identified in the PM in R&D. According to Werner and Souder (1997), R&D performance measures can be broadly divided into macro and micro measures where macro level approaches concentrate on the impact of R&D on the society as a whole and micro level approaches concentrate on the impact of R&D on the organizational dimension. The micro measures can be further categorized into quantitative (numerical), qualitative (non-numerical) and whether the measures are based on objective or subjective judgments (Werner & Souder, 1997). As discussed in section 3 the quantitative measures are easy to use and consume less time. However, Steele (1988) argues that quantitative measures are most of the time focused on readily quantifiable items rather than on R&D effectiveness. Further, quantitative measures focus more on technical processes, financial outputs and numerical outputs such as number of patents. On the other hand qualitative measures focus on the performance of individuals, teams, effectiveness of processes (Galloway, 1971) and provides a comprehensive and in depth perspective about R&D performance (Werner & Souder, 1997). However, the results get from qualitative performance measures can be biased and should be tailor made to suite the environment under consideration (Werner & Souder, 1997).

One of the earlier developed R&D frameworks was Brown and Svenson’s (1988) framework. This framework was developed by considering the R&D laboratory as a system and considering input (people, ideas, equipment etc.), output (patents, products, publications) and outcome (cost reductions, sales improvements etc.) based performance measures. In 1985, Moser carried out a survey and identified 14 categories of R&D performance measure. Most of the measures identified from this categorization, are output based measures such as quality of output, degree of goal attainment, amount of work done on time, percentage of project completion. Griffin and Page (1993) classified the measures into four groups as customer acceptance (customer satisfaction, customer acceptance, satisfaction of market share and sales goals), financial (break-even time, attain marginal and profitability goals), product level (development cost, launched on time) and firm level (% of sales by new products). The product level performance measures mainly concerns about the efficiency of the process where as the firm level measures concerns about the achievement of strategic objectives of the firm.

The categorization of R&D performance measures on to Kaplan and Norton’s Balanced Scorecard (BSC) can be identified in number of instances (Bremser & Barsky, 2004; Kersssens-van Drondelen et al 2000; Kersssens-van Drondelen, 1999; Kersssens-van Drondelen, 1997). They argue that the use of BSC (which
consist of Financial, Customer, Internal business process and Learning and growth perspectives) provides an integrated PM system to implement the strategy while comprehensively and appropriately covering the vital areas of PM in the R&D environment.

Godener and Soderquist (2004) identify three more classifications to measure the R&D performance, in addition to the four perspectives used in BSC. They are strategic measurement (strategic goal satisfaction), Technology management measurement (generation of new competitive products) and Knowledge management measurement (return on investment in terms of knowledge creation, knowledge transfer and knowledge exploitation). Coccia (2004) measured the performance of public research institutes using five measures (training, financing, national publications, teaching, international publications). In another research, the application of the EFQM (European Foundation for Quality Management) model can be identified for a research organization by assigning performance measures for customer, people, social and business attributes (Weggeman & Groeneveld, 2005).

The below section will lead this discussion towards identifying the value which can be gained by implementing a PM system within R&D activities.

VALUE OF PERFORMANCE MEASUREMENT TO RESEARCH AND DEVELOPMENT

Due to the rising cost, time and other resource constraints, much attention is paid on the success of R&D work where the managers are under pressure to monitor and improve the performance of R&D activities (Kerssens-van Drongelen, 2000). To gain the maximum outcome, the processes, and factors which influence the R&D work has to be continuously evaluated (Karlsson et al, 2004). Accordingly, Karlsson et al, (2004, 185) argues, “these processes, like everything else that has to be improved, have to be measured against some sort of data either historically or by expected output”. This can be achieved by implementing PM systems within R&D work as it helps to measure the outcomes against the targets (Bremser & Barsky, 2004).

Investors in R&D work play a vital role by providing necessary funds to undertake efficient and effective research. Thus, in the point of view of the investors, what ever the money spent on R&D work should be used to its maximum capacity. Consequently the argument which says “financial constrains negatively affect the freedom and the creativity of R&D activities” (Roussel et al, 1991) has been challenged due to the need of efficient and effective results from the R&D investments (Werner & Souder, 1997). Print (1999) recognized that some of the money spent on R&D activity is wasted and the managers are unable to identify and
locate the area where the money is wasted. In addition to the investors, shareholders are keen on knowing the contributions from R&D activities towards the development of the organization (Institutional Shareholders’ Committee, 1992). Therefore, such concerns from investors and shareholders on R&D spending have been demanded the need of showing the accountability of the resources spent on R&D work (Pearson et al, 2000; Wood, 1998; Nixon, 1998). The management has been forced to find ways of measuring the return on R&D expenditure and to evaluate the performance of R&D activities (Pearson et al, 2000; Nixon, 1998).

It is widely accepted that R&D as one of the main strategic issues that cannot be treated in isolation, but has to be aligned with the corporate strategy of the organization (Pearson et al., 2000; Roberts, 1988; Rogers, 1996; Roussel et al., 1991). Bremser and Barsky (2004) argue that the implementation of PM system would aid the strategy implementation of R&D activities. The research carried out in various industries indicate that their long term competitive advantage depends from commitment to on going R&D work and the use of PM systems to evaluate their success (Osawa & Yamasaki, 2005; Pearson et al., 2000; Kerssens-van Drongelen et al., 2000; Kerssens-van Drongelen & Bilderbeek, 1999; Werner & Souder, 1997; Tipping et al., 1995; Brown & Svenson, 1988). This justifies the advantages and competitiveness, which the organizations can be obtained by implementing PM systems within R&D.

The above sections discussed the development of R&D performance measures, strategic impact of PM in R&D and PM metrics and frameworks used for R&D work. Further, the value gained by PM in R&D in other industries also discussed. Fairclough (2002) report suggested that construction industry needs to learn and adopt research practices such as technology transfer and management of processes from other industry, which influences the performance of the industry (Koskela, 2002). Does the construction R&D process needs to implement PM system like in other industries? The section below will look into this aspect.

NEED OF PERFORMANCE MEASUREMENT TO CONSTRUCTION RESEARCH AND DEVELOPMENT

To get involved in high quality research, construction R&D requires resources such as necessary equipment, skilled individuals and funds (Seaden, 2002). Like in any other investment, the construction R&D investors expect reasonable returns from their investments (Seaden, 2002; Courtney, 1999). Therefore, the returns should be more calculable by means of establishing certain and visible relationships between the investments and output of construction R&D activities (Courtney, 1999). This can be done by implementing a PM system within the
construction R&D work. By doing so, the proper utilization of investments and clear links between investments and potential income can be clearly identified.

Identifying new ways to access technical solutions and creating new and improved products in the construction industry requires not only sufficient investments, but also commitment and time of the employees (Building Research Establishment, 2005). Thus, the time devoted for construction R&D should be justifiable. In addition to that, it is equally important to show that the results obtained through construction R&D activities are properly aligned with the expected objectives. This has demanded proper controlling and monitoring mechanisms, and a way to assess the goals against the outcomes. This can be achieved through implementing a PM system within the construction R&D work as such a system continually evaluate the successfulness of the activities, identifies the gaps between the goals and expected outcomes.

Cohen and Levinthal (1989, 1990) argue that R&D activities help to develop new information/knowledge as well as improve the ability of the organization’s absorptive capacity. The absorptive capacity is highly depend on the internal capabilities of the organization such as availability of qualified staff, the nature of internal and external communication, coordination and feedback mechanisms (Cohendet & Steinmueller, 2000; Steinmueller, 2000). Therefore, the management of internal R&D capabilities is essential for effective and efficient R&D activities. Gann (2001) states most of the construction R&D organizations do not have the required internal R&D capabilities. Further, Dulaimi et al (2002) recommend that the construction R&D activities should be coordinated to gain the maximum outcome. They emphasis the ability to develop superior products and services is significantly influenced by the level of corporation between the parties involved within the process. The implementation of PM system increases the communication, coordination, feedback mechanisms and directs the employees towards the common goals. Thus, a PM system within construction R&D work will improve the aforementioned internal capabilities and would generate successful results.

The need of training, participation to seminars, conferences is being identified to increase the skills and knowledge of people involved in construction R&D activities (Dulaimi et al, 2002). A properly designed PM system identifies such needs by looking into whether the R&D process is supported with the qualified people that are needed. Further, PM helps to control, monitor and allocate the organizational resources (Melynky et al, 2004; Love & Holt, 2000). Accordingly, by implementing a PM system, construction R&D can properly handle the resources, which they are accountable for.
CONCLUSION

Many organizations tend to evaluate the successfulness of R&D activities, to identify how well they are performing. The inadequacy of using financial measures as the sole criteria for PM in R&D has led to the development of non-financial measures. Deriving the R&D performance measures from the strategy of the organization was highlighted due to the strategic impact of PM within R&D.

In terms of the construction industry, insufficient investments for R&D activities have demanded a way of showing the accountability of resources and making the R&D outcomes more calculable. Further, the lack of internal R&D capabilities has hindered the efficiency and effectiveness of construction R&D activities. Therefore, the need for PM in construction R&D was revealed from this paper, which will add value in terms of proper utilization of resources, identifying the actual contributions of R&D activities, aligning the outcome of R&D with the expectations, and increasing the internal R&D capabilities.

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