Factors for analysing and improving performance of R&D in Malaysian universities

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This paper presents a model for analysing and improving performance of R&D in Malaysian universities. There are various general models for R&D analysis, but none is specific for improving the performance of R&D in Malaysian universities. This research attempts to fill a gap in the body of knowledge with regard to developing countries by explicitly focusing on factors that are relevant for analysing and improving R&D performance in Malaysian universities.
The project's methodology essentially entails a deductive route to identify and progressively refine the factors that determine R&D performance. It is based on extensive literature study aimed at developing a model that is appropriate for researching and improving R&D in an emerging economy. The paper addresses the development of the model and the research project's approach. This model will be applied in collecting data from surveys and a number of field studies. The results will be used to improve the model as well as recommending points of improvement for Malaysian universities.

1. Introduction

The role of R&D has grown to assume great importance in many developed and developing countries including Malaysia. This is demonstrated by increasing investments on R&D in many sectors including government, academia and industry. This is based on the assumption that there is a positive relationship between amounts of resources allocated to R&D and R&D output and, therefore, the higher R&D expenses, the more effective the output.

Despite the high expenditure on R&D and the general desire for invention and for innovation, many R&D ventures do not achieve their expected performance. This problem is particularly severe and complex in the case of universities in Malaysia. The problem is not only to measure how effective their R&D is, but also how to make them more effective in their R&D performance. This is a question closer to the problem of organisational efficiency in understanding industry's needs, translating those to the organisational strategic technological direction, having the required type of resources such as trained personnel and enough funds for undertaking R&D, efficient R&D management, and finally transferring R&D results to the production system or market place. Market driven R&D encompasses all aspects of organisation of R&D.

Macroeconomic studies have shown that there is a strong relationship between long-term profitability and investments in R&D (Collier, Mong and Conlin, 1984; Nelson, 1986; and Fagerberg, 1987). Nevertheless, in the strategic management field, existing approaches have demonstrated that long-term growth can be brought back to the ability to identify and cultivate core capabilities and competences of the corporation and that this does not mean outspending rivals in R&D but being effective (Prahalad and Hamel, 1990). In other words, the existing competitive environment, in which competition increases

and the pace of technological change accelerates, stresses even more the need for deploying R&D investments more efficiently and more effectively (Foster et al., 1985; and Roussel et al., 1991). Companies well known for their innovative capabilities frequently spend far less than do their less effective competitors (Chiesa and Masella, 1996).

Bolwijn and Kumpe (1990), Roussel et al., (1991), and Kumpe and Bolwijn (1994) have extensively described the evolution that has taken place in the management practices of many R&D organisations in response to all these increased pressures on R&D. They have outlined a transition from "a strategy of hope" characterised by the expectation that, given the right mix of brains, money, equipment and time to pursue ideas, scientists and engineers, left alone, will concoct new profitable products and processes, to a strategically and organisationally embedded form of R&D management. In this R&D management concept, R&D strategies and business strategies are closely linked at both the strategic and the operational level (Robb, 1991; Chester, 1995).

Doing R&D is a challenging task and managing R&D is no less daunting. Therefore, urgent efforts are required to understand better the nature of R&D activities in Malaysian universities, identify factors of greatest importance in success of the process, and identify ways to facilitate better performance of R&D in this sector, because there is no doubt that a tremendous increase in resources devoted to R&D in this sector is needed, but not sufficient. The project's methodology for analysing and improving R&D performance in Malaysian universities essentially entails a deductive approach to identify and progressively refine the factors that determine R&D performance.

2. Overview of R&D in Malaysian universities

Malaysia is a developing country without a strong tradition of R&D. R&D stood at only 0.50% (2000) of the Gross Domestic Product (GDP) as compared to more advance countries such as Japan 2.8% (1999), USA 2.65% (1999), Germany 2.38% (1999), and France 2.17% (1999). From the National R&D Survey (MASTIC, 2000, see Table 1), it is revealed that the expenditure on R&D had increased to an all-time high of RM1671.5 million (~ Euro407.68 m) in 2000, a boost of 48% from that of 1998. As a result, the Gross Expenditure on R&D to the Gross Domestic Product (GERD/GDP) ratio had risen from 0.39% in 1998 to 0.50% in 2000. This is very encouraging considering the fact that barely two years before 2000, Malaysia was in the midst of a regional economic downturn.

Table 1. R&D Expenditure in Malaysia in 2000 (RM1 million ~ Euro216 000)

Research and Development	
Private Sector	1,556 Projects
Government Agencies and Research Institutes.	1,483 Projects
Institutions of Higher Learning (universities)	2,296 Projects
Total	5,335 Projects
Organisations with R&D	
Private Sector	195 organisations
Government Agencies and Research Institutes.	43 organisations
Institutions of Higher Learning (universities)	14 organisations
Total	252 organisations
Expenditure	
Gross Expenditure on R&D (GERD)	RM 1,672m
The GERD/GDP Ratio	0.50%
Current Expenditure	RM 808m
Labour Cost	RM 401m
Operating Cost	RM 407m
Capital Expenditure	RM 864m
Three Main Field of Research	
Applied Sciences and Technologies	RM 528m
Information, Computer and Communication Technology	RM 382m
Engineering Sciences	RM 301m
Three Main Socio-Economic Objectives	
Manufacturing	RM 677m
Natural Sciences, Technologies and Engineering	RM 308m
Information & Communication Services	RM 177m
Manpower	

Total R&D Research Personnel	23,262
Total Number of Researchers	15,022
Total Full Time Equivalent for R&D Personnel	10,059.67
Total Full Time Equivalent for Researchers	6,421.65
Full Time Equivalent per R&D Personnel	0.43
Full Time Equivalent per Researcher	0.43
Degree Holders (Ph.Ds, Masters, Bachelors)	13000
Number of Researchers per 10,000 Labour Force	15.6
R&D Cost Per Research Personnel	RM 71,855

Source: MASTIC (2000) National Survey of Research and Development

There was an overall increase in expenditure for the three main sectors, i.e. Institutions of Higher Learning (universities), Government Agencies and Research Institutes and the private sector. Universities recorded the highest percentage increase in expenditure from RM133.6 million in 1998 to RM286.1 million in 2000 (see Figure 1). Increased R&D funding in universities clearly indicated greater commitment among research personnel and academic staff in carrying out R&D projects. There were 2296 research projects carried out by various faculties, departments, and R&D units in Malaysian universities in various Fields of Research and with different Socio-Economic Objectives.

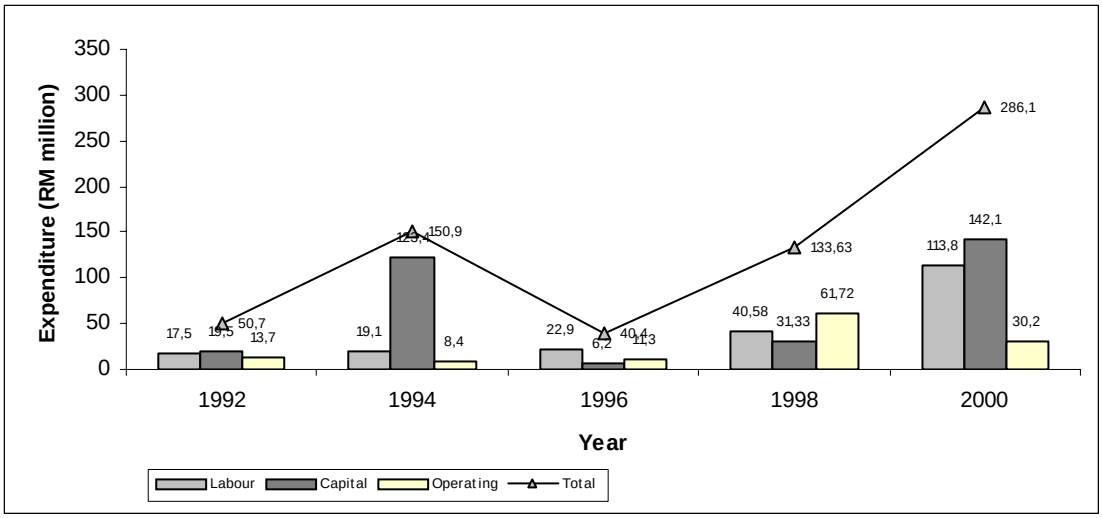

Figure 1. The Malaysian universities expenditure on R&D for the period 1992-2000 (source: MASTIC, 2000)

A notable feature of Malaysian universities R&D scene is that the paradigm shift in terms of Field of Research (FOR) and Socio-Economic Objective (SEO). Taken in a positive light this change may be perceived to reflect the adaptability of the researchers in meeting the changing demands of global R&D. On a less positive note, the changing SEO or FOR may be taken as an indication that some researchers were prone to jumping on to a new band wagon whenever something new or novel appear on the horizon. In R&D, focus and direction is of paramount importance especially in Malaysian relentless efforts to find a niche in the competitive and challenging R&D world.

Various factors still hamper R&D ventures. In the 2000 survey, “No future direction”, “Lack of commitment from top management” and “No priority and trust area” were considered by most universities as major internal factors that limited their R&D activities (see Figure 2). In general, three major external factors that limited their R&D activities were: “Shortage of R&D personnel with requisite expertise”, “Increasing capital costs” and “Lack of government incentives”. However, a larger percentage (almost 14%) of the respondents said that “Shortage of R&D personnel with requisite expertise” was the external limiting factor (see figure 3). In 1998, “Limited financial resources” was considered as a major internal limiting factor and the major external limiting factor was “Increasing capital costs”. In 1996 and 1994, “Delay in making decision” was the major internal limiting factor and the major external limiting factor was “Shortage of personnel”. Some of these limiting factors, if not addressed, can hamper progress of R&D in Malaysian universities. Therefore the research project will use the data above as a basis for developing research model and methodology.

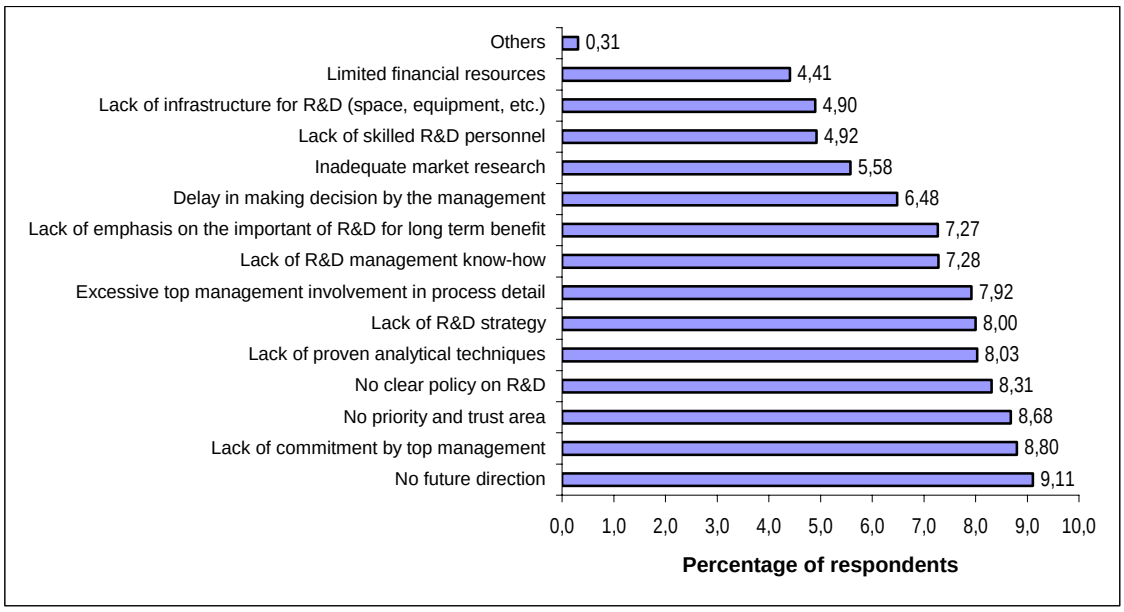

Figure 2. Internal factors limiting R&D activities in Malaysian universities (source: MASTIC, 2000)

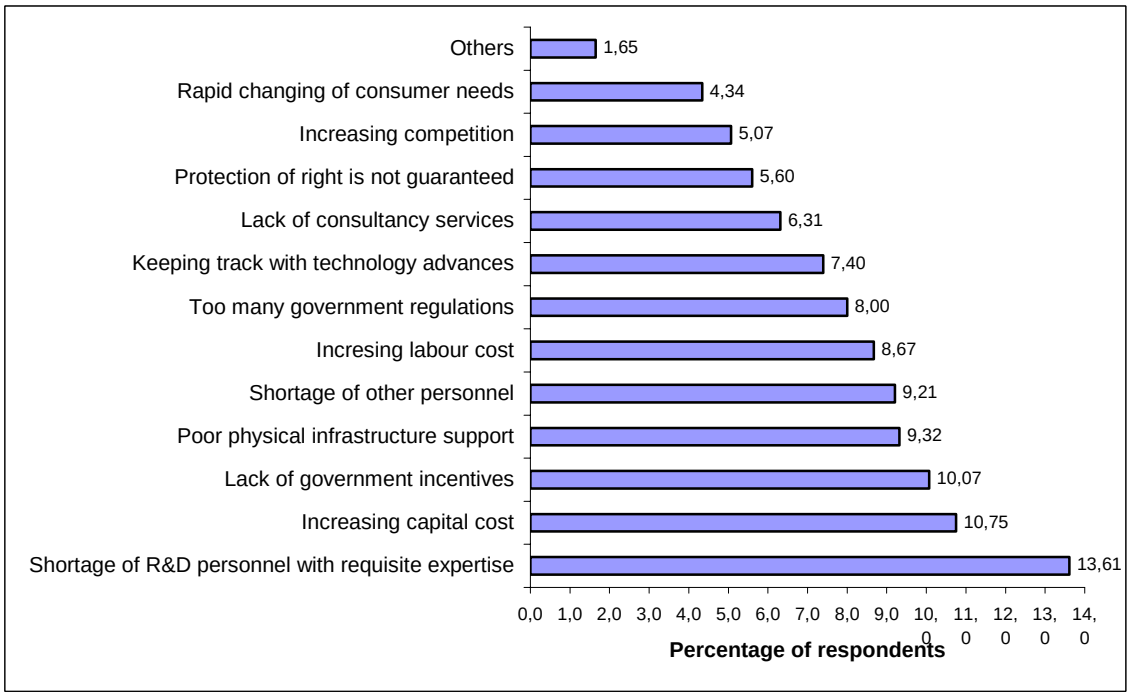

Figure 3. External factors limiting R&D activities in Malaysian universities (source: MASTIC, 2000)

3. Literature review

The concept of R&D as a process has been acknowledged, which indicated the causal relationships among various R&D elements, in search of those factors of greatest importance in success of the process. Quinn (1960) was probably one of the first authors to apply the causal chain concept to performance in R&D. Most elements of the framework presented almost three decades later by Brown and Svenson (1988) were already there. A few other simple models of R&D process have also been proposed (e.g., by Thompson, 1967; Freeman, 1974; and Dumbleton, 1986). The Brown and Svenson (1988) framework has been widely used, though sometimes slightly adapted in R&D management research (e.g., Schumann et al., 1995; Lee et al., 1996, and Kerssens-van Drongelen, 1999).

Besides the approach of applying R&D process models, another mainstream of research on R&D concerns the examination of actual case histories of successful and less successful R&D organisations in order

to identify the important factors. Studies that have been published concerning determinant and constraint factors affecting performance of R&D are, for example Brown and Eisenhardt (1995), Foster et al. (1985), Griffin and Page (1993), Gupta et al. (2000), Jain and Triandis (1990), Jordan et al. (2003), Kerssens-van Drongelen (1999), MASTIC (2000), Menke (1997), Neufeld et al. (2001), Ransley and Rogers (1994), Shenhar et al. (2002), Szakonyi (1994), Thailand (2001), The Management Roundtable (1997), and Twiss (1980). They revealed the significance of some inputs to R&D process, some organisational and managerial factors that influence R&D processes and some elements in transferring R&D results to the receiving system.

Criteria from other perspectives are also taken into consideration in model building of this study, such as innovation and technology management (e.g., Burgelman et al, 2004; Dussauge et al., 1992; Granstrand, 1994; Khalil, 2000; Narayanan, 2001; Pavitt, 1999; Phaal et al, 2001; Porter, 1991; Roberts, 1995; Tidd, 2000; and Tidd et al., 1997), organisational performance (Kaplan and Norton, 1996), organisational effectiveness (e.g. Cameron 1978 and 1986; Quinn and Rohrbaugh, 1983), operational productivity (Prokopenko, 1987), and TQM (Hardjono, 1995; Marrewijk and Hardjono, 2003; and McLaughlin, 1995).

As part of the exploration of literature on R&D management, searches were also conducted for aspects of the macro Malaysian context that could influence the performance of R&D and hence need to be addressed in the model (e.g., the Eighth Malaysian Plan, Industrial Master Plan I and II, Malaysian Science &Technology Indicators, National Survey of R&D, National Survey of Innovation).

4. Conceptual research framework

There are several general frameworks for R&D analysis, which are applicable to the R&D situation in Malaysian universities. Dumbleton (1986) presented a simple linear model of the R&D process, which includes “input”, “R&D”, “product development”, “production” and “output”. Brown and Svenson (1988) proposed a framework of R&D laboratory as a system, which includes inputs, processes, outputs, receiving system and outcomes (see Figure 4).

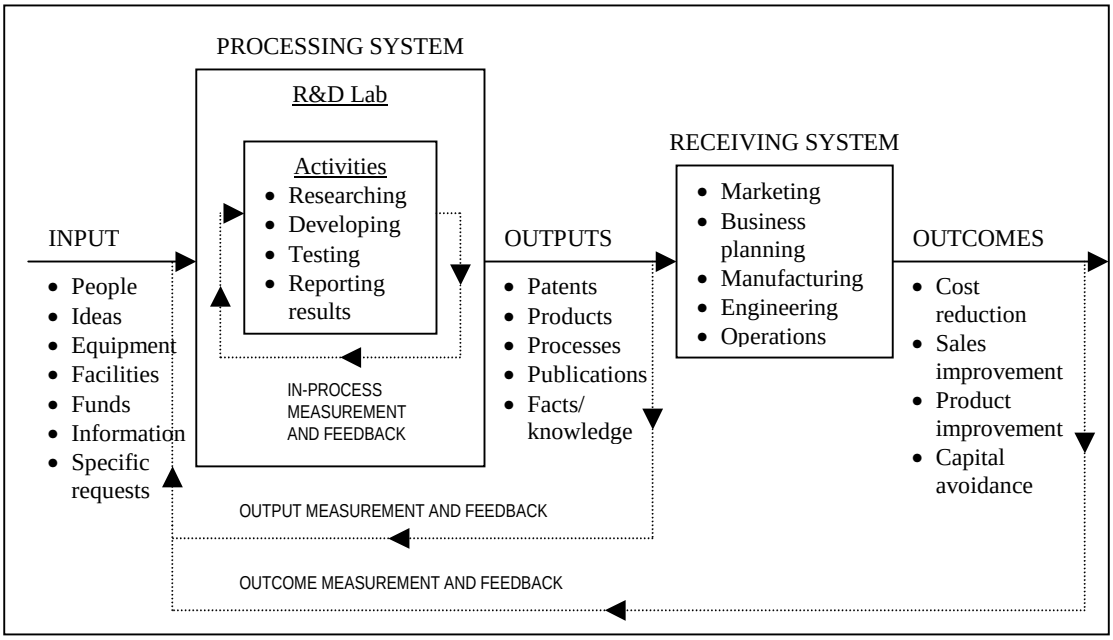

Figure 4. The R&D process (Brown and Svenson, 1988)

Schumann et al. (1995) slightly adapted the Brown and Svenson (1988) model. Lee et al. (1996) considered the entire R&D process, which includes input, throughput, output and outcomes. Others who have studied organizational aspects besides output and outcome, or who have considered the entire process include Brown and Gobeli (1992), Ranftl (1978), Steele (1988), and Szakonyi (1994). Narayanan (2001) also used almost the same framework to describe firm level innovation, which includes drivers, process and outputs. Drivers include market factors and input factors that are influenced by the macro environmental trends (economic, social, political and regulatory trends). McLaughlin (1995) presented the environment surrounding the R&D system, which includes culture/emotional environment, business climate and type of business/business systems. Dumbleton (1986) and Kerssens-van Drongelen and Bilderbeek (1999) also acknowledged that context/contingency factors are critical factors affecting the R&D environment. A framework, which is slightly adapted from the above literature, is proposed for analysing factors to improve R&D performance in Malaysian universities (see Figure 5).

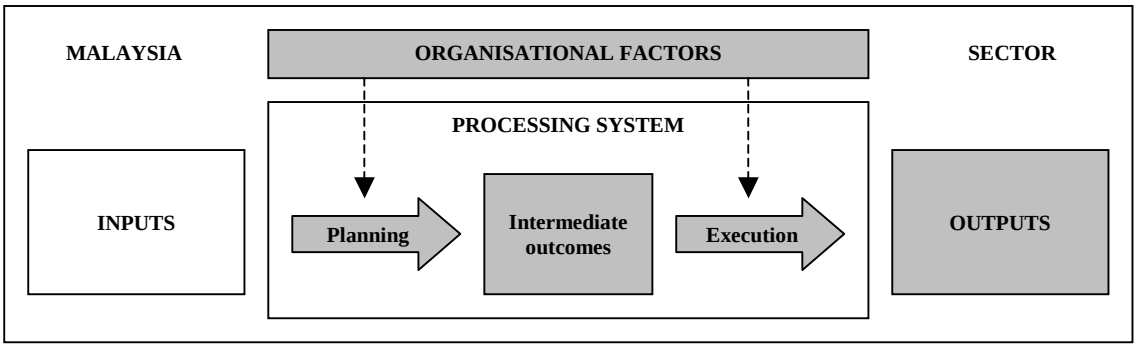

Figure 5. A framework for studying factors to improve R&D performance in Malaysian universities

The R&D process is a complex, adaptive, and on-going social system. In this framework, R&D is regarded as a "black box" in which undefined processes occur which result in an output. The inter-relationships between labour, capital and the social-organisational environment are important in the way they are balanced and co-ordinated into an integrated whole. Performance improvement depends upon how successfully the main factors of the R&D process are identified and used. It is important, in connection with this, to distinguish three main performance factor groups, i.e. resource (input) related, job (process) related, and environment related (Prokopenko, 1987). This framework clearly distinguishes the input related factors, process related factors and organisational factors that could influence the processing system, and consequently affect the output. In addition, this framework also includes "MALAYSIA" and "SECTOR" context or contingency factors as the environment surrounding the R&D system in Malaysia.

Inputs are the raw materials or stimuli a system receives and processes. The R&D organisation inputs are people, information, ideas, equipment, facilities, specific request, and the funds needed to complete various R&D activities. The processing system is the R&D lab itself, which turns the inputs into outputs by writing proposals, conducting research, testing hypotheses, reporting results, and so on (Brown and Svenson, 1988).

According to Mukherjee and Singh (1975) any performance improvement drive which plans to deal with external (not controllable) and internal (controllable) factors affecting the management of the organisation must take such factors into consideration during the planning phase of the programme, and try to influence them by joining forces with other interested parties. Lee et al. (1996), McLaughlin (1995), Pinto and Slevin (1989) and Szakonyi (1994) are among others who have clearly distinguished R&D planning and R&D implementation phases and their outcomes/consequences. Various measuring scheme/evaluation criteria have been proposed to check and balance these outcomes/consequences (Brown and Gobeli, 1992; Lee et al., 1996; McLaughlin, 1995; Pinto and Slevin, 1989; Ranftl, 1978; Steele, 1988; and Szakonyi, 1994). They also revealed particular organisational factors affecting the R&D planning and implementation phases. In general, these organisational factors include all soft factors, such as leadership, direction, organisational system and procedures, management styles and work methods, motivation, and etc. (Prokopenko, 1987). In this framework (Figure 5), the planning phase is emphasised as an important event in the processing system, which produces the intermediate outcomes. These intermediate outcomes are important as measuring scheme/evaluation criteria to be checked and balanced before proceeding to the next event, i.e. execution. This framework also highlights the organisational factors that influence both planning and execution phase.

These elements from inputs, processing system, organisational factors, and Malaysia and sector context/contingency factors are collectively contributing to the ultimate goal of R&D in Malaysian universities. Brown and Svenson (1988) listed the typical outputs include patents, new products, new processes, publications, or simply facts, principles, or knowledge that were unknown before.

5. Factor/variance approach versus process approach of model building process

Based on Mohr (1982), research models can be classified into "variance" models and "process" models. In variance theories, the precursor is assumed as both a necessary and a sufficient condition for the outcome. In process theories the precursor is assumed to be insufficient to "cause" the outcome, but it is held to be necessary for the outcome to occur. In general, necessary conditions alone cannot constitute a satisfactory theory. However, the necessary conditions can comprise a satisfactory causal explanation if they are combined and strung together in such a way as to tell the story of how the outcome occurs whenever it does occur (Hoogeveen, 1997, p. 52-53).

Variance theories differ from process theories in the assumptions made about the relationship between antecedents and outcomes. Variance theories posit an invariant relationship between causes and effects when contingent conditions exist (Markus and Robey, 1988; Mohr, 1982; Newman and Robey, 1992; and Pettigrew, 1990). This strategy of "explaining variance," however, often neglects to "explain" exactly how or why the predictors and outcomes are related. That is, it does not

provide evidence of the phenomena (events, actions, and so on) that link the independent and dependent variables (Newman and Robey, 1992). Even where causal modelling is used (e.g., Lucas et al., 1990; Robey et al., 1989), causal connections are assumed to exist rather than are demonstrated empirically. Factor models, therefore, do not explain how outcomes occur; they associate a level of outcome with a level of predictor, inferring the causal linkages between the two.

A complementary alternative to the factor approach is the process approach, which focuses on the dynamics of social change, explaining how and why the results of the development efforts are achieved (Mohr, 1982; Van de Ven and Huber, 1990). Process models provide the story that explains the degree of association between predictors and outcomes. Process models focus on sequences of events over time in order to explain how and why particular outcomes are reached (Mohr, 1982; Newman and Robey, 1992; Robey et al., 2002). Another characteristic of a process model is that it is better at explaining conditions that are only necessary, but not sufficient for a certain outcome. Process theories assert that the outcome can happen only under these conditions, but that outcome may also fail to result. Process theories allow for the possibility that other, more powerful, causal factors will influence the outcome, and evoke the possibility of spurious epi-phenomenal relationships (Soh and Markus, 1995). They do so by combining necessary conditions in a "recipe" (Mohr's term, 1982), involving a combination of necessary conditions with probabilistic processes in a specified time sequence.

A process approach is usually used to better understand how change actually emerges, develops, grows or terminates over time (Markus and Robey, 1988; Van de Ven and Huber, 1990). Recently there has been a wider use of the process approach to understand and explain the complexity of innovation processes. Many diffusion of innovation theories are process theories, at least implicitly (Markus and Robey, 1988; Barley, 1986). Thus in this research, a process model of R&D in Malaysian universities that incorporates a number of factors is developed, considering R&D as a process with a sequence of discrete events that lead to outcomes of particular interest, or as a sequence of stages, in which related activities occur over time. For example, "Planning" assumes dynamic properties when conceived as a process. A positive feature of process models is their faithful account of actual experiences, although they can become cumbersome and analytically complex (Kling, 1987; Markus and Robey, 1988). However, process models do adopt a specific form and should not be discounted as unscientific or less rigorous than factor models (Newman and Robey, 1992).

6. Research model

Based on the conceptual framework, a research model has been developed (see Figure 6). This model consists of a few phases in sequence to represent the R&D process in Malaysian universities, starting with input, followed by throughput (planning, intermediate outcomes and execution), which are influenced by respective organisational factors at each phase, and then collectively produce output. The internal R&D process is surrounded by the external R&D environments, which are influenced by Malaysian and sector context/contingency factors.

The input includes "R&D personnel with requisite expertise", "Funds", "Incentives", Equipment and Facilities", "Ideas/creativity", "Information" and "Specific requests". "R&D personnel with requisite expertise" was considered by most researchers in Malaysian universities as the major external factor limiting R&D activities (see Figure 3). Schumann et al. (1995) distinguished "people" (an input factor in Brown and Svenson, 1988) as technical professional with technical vitality. Gupta et al. (2000) emphasised in their study the importance of key skills/knowledge domains of the R&D personnel. The second major external factor limiting R&D activities in Malaysian universities was "Increasing capital cost" (Figure 3), which is mostly related to fund (as in Brown and Svenson's model, 1988), thus it is listed as "Funds" in this model (Figure 6), even though capital allocation for R&D has increased in recent years (see Figure 1). The third external factor "Lack of government incentive" (Figure 3) is added to the model as incentives, since there are various types of incentives to the universities researchers/scientists, i.e. intrinsic and extrinsic rewards, as well as monetary and other types of bonuses. The fourth external factor "Poor physical infrastructure support" (Figure 3) is represented in this model as "Equipment" and "Facilities" as proposed by Brown and Svenson (1988). "Lack of infrastructure for R&D (space, equipment, etc.)" was also mentioned in the internal factors limiting R&D activities in Malaysian universities (Figure 2). Ideas/creativity and information are also included as input factors in the model, since they were included in Brown and Svenson's model (1988) and others (e.g. Dumbleton, 1986; Jain and Triandis, 1990; McLaughlin, 1995; and Twiss, 1980). "Specific requests" is included in the model as an input factor, because it was included in Brown and Svenson (1988) and also a common practice in Malaysian universities that some of the research projects are top down from the management, government or demanded by industries.

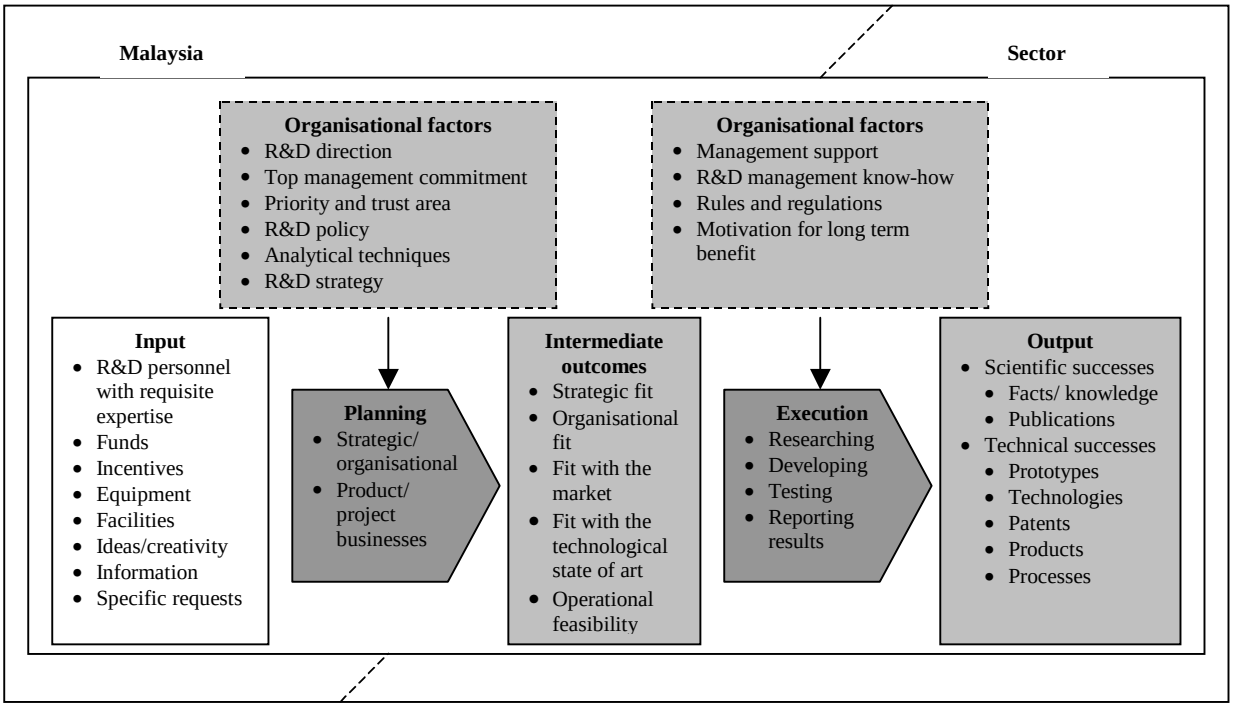

Figure 6. The research model

The planning stage is very crucial in R&D because, besides to get approval and funds from top management and government or industries, the prime rationale of planning in R&D is to ensure doing the right things and to do it rightly. In other words, planning in R&D ensures that it fits within the strategic/organisational, market and technological directions and ensures smooth running of the project activities, efficiently (include speedy) and productively (innovative). Dumbleton (1986), Foster et al. (1985), Lee et al. (1996), McLaughlin (1995), Menke (1994), Pinto and Slevin (1989); Ranftl (1986), Schmitt (1991) and Szakonyi (1994) are among others who acknowledged the importance of good R&D planning to ensure effectiveness, efficiency and productivity. In general, there are two levels of planning involved in R&D organisation, i.e. first the strategic/organisational planning, and second, the product/project businesses. Most of the R&D projects in Malaysian universities are bottom up projects, which require the researchers to prepare proper planning (i.e. proposal, budget, milestone, expected results, etc.) in order to get approval and funds from the management and government or industries. There are also specific requests from top down, but the detail planning normally done by the researchers, sometimes competes with others (in terms of the best proposal/planning/budget) for approval and funds from management and government or industries.

There are several organisational factors that influence the planning process. “No future direction”, “Lack of commitment from top management”, “No priority and trust area”, “No clear policy on R&D”, “Lack of proven analytical techniques” and “Lack of R&D strategy” were considered by most researchers/scientists as the major internal factors limiting R&D activities in Malaysian universities (see Figure 2). Thus in this model, these factors (R&D directions, top management commitment, priority and trust areas, R&D policy, analytical techniques and R&D strategy) are emphasised as the organisational factors that influence planning.

The intermediate outcomes are treated as consequences of planning, which yields “the right things” (i.e. strategic fit, organisational fit, fit with the market and fit with the technological state of art) and to ensure “doing things rightly” (operational feasibility). The importance of these elements was acknowledged by many writers in technology and innovation management (such as, Burgelman et al, 2004; Dussauge et al., 1992; Granstrand, 1994; Khalil, 2000; Narayanan, 2001; Pavitt, 1999; Phaal et al, 2001; Porter, 1991; Roberts, 1995; Tidd, 2000; and Tidd et al., 1997).

The real R&D stage is the execution of the planned activities, which include researching, developing, testing and reporting results as pointed by Brown and Svenson (1988). Many authors (Brown and Gobeli, 1992; Lee et al., 1996; McLaughlin, 1995; Pinto and Slevin, 1989; Ranftl, 1978; Steele, 1988; and Szakonyi, 1994) mentioned particular organisational factors, which influence the performance of this stage. “Management support”, “R&D management know-how”, and “Motivation for long term benefit” (see Figure 2) are considered as the most important internal factors limiting R&D activities at this stage. “Rules and regulations” is important as the feed-forward control mechanism of the execution phase (Dumbleton, 1986; Jain and Triandis, 1990; and McLaughlin, 1995). Thus these factors are listed as the organisational factors that influence performance in the execution of R&D.

The final stage of the process is the output as collective consequences of the preceding events. Typical outputs of universities R&D include scientific successes (i.e. facts,

principles, or knowledge and publications) and technical successes (i.e. prototypes, technologies, patents, new products and new processes).

Values, norms, visions, perceptions of Malaysia form a part of the culture for R&D organisations (Jain and Triandis, 1990; and McLaughlin, 1995). Traditionally, Malaysia has been an agricultural economy and industrial R&D is just new to the country. This is highlighted in the Vision 2020, which is by the year 2020 Malaysia is expected to advance in science, technology and industry. This factor influences the R&D environment in Malaysia. In addition, the political stability and socio-economic progress affect the sector development in R&D. Thus Malaysian and sector context/contingency factors are also included in the model as the external forces that influence the performance of R&D in Malaysia.

Compared to the Competing Values Framework proposed by Quinn and Rohrbaugh (1983) and Jordan et al. (2003), which incorporates four common models of organisational effectiveness, i.e. the human relation model, the open system model, the rational goal model, and the internal process model, this research model could be classified as the rational research model. It emphasises the value of control and stability over flexibility and readiness. An effective organisation from this perspective is discussed in terms of planning and goal setting, which results in productivity and efficiency.

7. Conclusions

This paper presents initial work to develop a model for analysing and improving performance of R&D in Malaysian universities. The study employs a deductive approach to identify and progressively refine the factors that determine R&D performance. It includes an extensive literature study aimed at developing a model that is appropriate for researching and improving R&D in an emerging economy. The model is to be applied in collecting data from surveys and a number of field studies. The results will be used to improve the model as well as recommending points of improvement for Malaysian universities.

The findings propose a process approach, which is adapted from Dumbleton, (1986), Brown and Svenson (1988), and other inputs from organisational aspects (such as Brown and Gobeli, 1992; Lee et al., 1996; McLaughlin, 1995; Pinto and Slevin, 1989; Ranftl, 1978; Steele, 1988; and Szakonyi, 1994). A process approach is suitable for explaining conditions that are only necessary, but not sufficient for a certain outcome. Process theories allow for the possibility that other, more powerful, causal factors will influence the outcome, and evoke the possibility of spurious epi-phenomenal relationships. They do so by combining necessary conditions in a "recipe", involving a combination of necessary conditions with probabilistic processes in a specified time sequence.

In the conceptual framework and research model, R&D in Malaysian universities is considered as a process, which include input factors, processing system (planning, intermediate outcomes and execution) that are influenced by respective organisational factors and then collectively produce outputs. The Malaysian and sector context/contingency factors are also considered in the framework and model as the critical factors surrounding the R&D environment in Malaysia.

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