Innovation Process: A Review of Existing Models and Development of an Alternative Model

Suziyana Mat Dahan [1], Nurhaizan Mohd Zainudin [2], Lee Chia Kuang [3], Mohd Yusof Taib [4]

[1, 2, 3] Faculty of Manufacturing Engineering and Technology Management, UMP
[4] Faculty of Mechanical Engineering, UMP

Corresponding email: suziyana@ump.edu.my

Abstract

The intense competition in today's global business environment has forced the manufacturers to innovate products more often. However, innovation process is risky and manufacturers often aim to introduce new products with lower development costs, shorter lead time and better quality. Thus, an appropriate innovation model needs to be developed to ensure that the objectives can be met. Previous works on product innovation revealed that a number of innovation models with different concepts and compositions have been produced and validated. The studies showed that previous researches were having disagreement on not only the most effective model of innovation, but also the key elements that affect a business's ability to produce a successful innovation. This paper presents a review of the work related to innovation process including: the need for systematic innovation process, current models of innovation process and key elements of successful innovation. This paper then highlights the developments of an alternative innovation model, which focuses on the application of functional build (FB) approach to manufacturing process as an essential control element of the final product specifications.

Keywords: Innovation process, Innovation models, Elements of innovation, Functional build

1. INTRODUCTION

Innovation is crucial in determining its continuation in today's rapid changing business environment. A business which fails to react quickly to the changes of any entity in the environment is exposed to the risks of being overtaken by its competitors. However, investing money in producing new product is risky and a business often targeting to meet three critical objectives when engaging in new product innovation process: to reduce development costs, to reduce product lead time and to improve product quality [1]. In addition, the shorter product life cycles has raised the need for manufacturing products effectively and efficiently and therefore increases the need to develop a reliable innovation model to ensure that the objectives can be achieved.

Environmental change has lead to the change in the innovation models employed by businesses as they need to respond to the new competitive settings [2]. The new competitive conditions have made the previous models to become obsolete and forced the businesses to consider new factors in their innovation practice which have resulted the introduction of new product innovation models. Many versions of innovation models have been developed and validated by previous researchers. A review of the major models showed that each of them has associated with strengths and weaknesses and has been used as guide in improving the models to produce more relevant models.

New product innovation processes are resulted from the existence of various elements. A range of elements which determine the successfulness of the innovation process have been identified in previous studies. There are disagreements among the researchers about what exactly the factors that contribute to the success of innovation process. Functional Build (FB) approach to manufacturing validation is one of the technology elements which can be applied to improve the innovation process. According to Hammett, Wahl and Baron [3], FB approach could help to reduce validation time and costs while meeting the end product quality requirements through the use of flexible criteria in validating the products. It concerned more on meeting the final build specifications than the design specifications of components which constitute the product.

2. THE NEED FOR SYSTEMATIC INNOVATION PROCESS

It was estimated that approximately 50% of innovative efforts failed and ineffectiveness of the implementation process of innovation has been recognised as being the cause of the failure [4]. While a worldwide survey done by Arthur D. Little in 1991 revealed that the obstacle that hinders 87% of Japanese respondents to improve product innovation was a lack of systems and guidelines for product development [5]. Indeed, such failure has caused a great amount of investment being wasted. A report by financial giant Morgan Stanley forecasted that out of $2.7 trillion, more than $500 billion is wasted due to the innovation failure in 2002 [4]. This shows that businesses need to pay intense attention on overcoming the causes of the implementation failure that is by having a planned innovation process.

According to Beacham [6] and Bacon and Butler [7], innovation is best carried out in a systematic and disciplined manner particularly when creating a completely new product for a new market. Jones [8] and Jones and Stevens [9] indicated that models have been used to describe the various stages of innovation process and allow businesses to organise the process and make decisions more effectively. The innovation models are presented as containing varying number of steps, stages and activities [10]. In short, the implementation of systematic innovative activities is represented through the modeling of the innovation process in providing strategic direction to business in order to attain the expected results.

3. EXISTING MODELS OF INNOVATION PROCESS

A number of innovation models have been tested by researches years ago such as by Booz, Allen and Hamilton in 1982, Walker in 1986, Cooper in 1988, Hart and Baker in 1994, and Trott in 2002 [5, 11, 12]. Cooper has introduced and validated stage-gate model which separated the stages of the innovation process by check points called gates [13] such as depicted in **Figure 1**. It is a kind of control model at which information is gathered and development risks are evaluated before deciding whether the product development project should be continued or not [14]. According to Cooper [15] in [13], the model is proven to increase profitability of the product, shorten the time-to-market, and increase the possibility of observing possible mistakes in an early phase of the development process. However, the model has been criticised due to the reliance on the internal sources of information, the chances of limiting the creativity and the difficulty in defining the 'go' and 'no-go' measures [14]. The model is useful in minimising the product innovation failure since errors are detected as early as possible, but it ignores the importance of detail development process and feedback in creating new products.

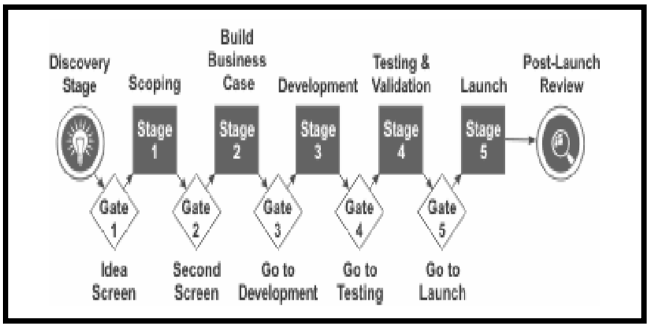

Figure 1: The stage-gate model
Source: [13]

A different model has been developed by Ulrich and Eppinger such as shown in **Figure 2** which was indicated by Timonen [13] as one of the famous models of innovation process. The model emphasise the roles of different functions of the business at each stage of the process. However the model is limited with the same problem as Cooper's model because of the explicit stages that are showed on the process.

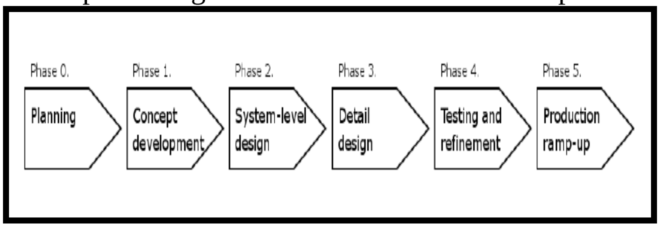

Figure 2: The innovation model developed by Ulrich and Eppinger (2003)
Source: [13]

According to Hart and Baker [5], Saren (1984) has classified the innovation models into five categories: departmental-stage models, activity-stage models, decision stage models (similar with the one suggested by Cooper), conversion process models and response models. Trott [12] has later on identified another two models in addition to Saren's model which were known as cross-functional models and network models. However, network models (shown in **Figure 3**) seemed to be the most relevant since close interactions with the external entities of business environment lead to the use of variety of information to produce products that best meet the market needs.

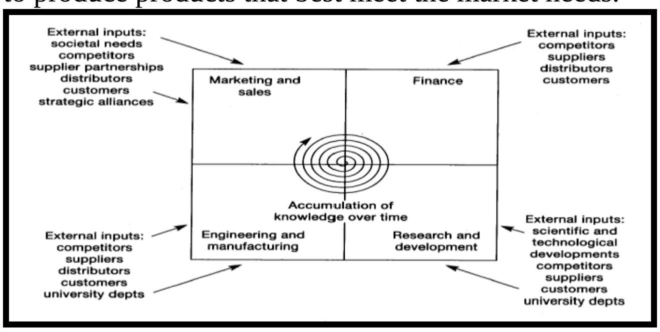

Figure 3: Network model of innovation
Source: [12]

Rothwell in [16] described the five generation evolvement of innovation process models. The coupling model (third generation), the integrated model (forth generation) which are portrayed in **Figure 4** and **Figure 5** respectively, and the network model (fifth generation) are similar in terms of their focus on the importance of close interaction (i.e. networking activity) between the various departments of the business and with the external parties in product development. The network model (fifth generation) is identical to the one that was introduced by Trott [12]. Rothwell [17] noted that the fifth generation innovators were having resource constraints and the ability to speed up the product development process provides great advantages to them. Studies have demonstrated that shorter product lead time enables businesses to gain higher market share, profit and other long-term competitive advantages [16, 17, 18]. Hence, they were emphasising on utilising the networking and integrated strategies in new product development [17].

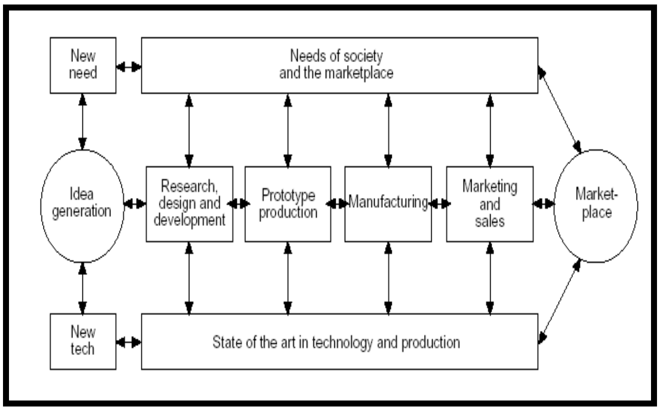

Figure 4: Coupling model of innovation (Third Generation)
Source: [16]

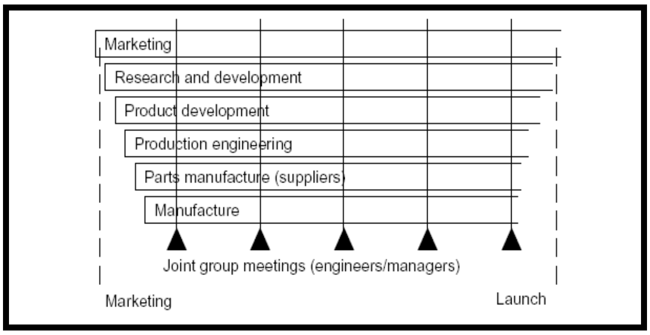

Figure 5: Integrated model of innovation (Forth Generation)
Source: [16]

In spite of the existence of different versions of innovation model, the terminologies and the activities that constitute these models are also varied. Van Der Zee who compared 90 different models in 2003, found out that more than 1,248 different terms were used to set a 54 innovation activities [19]. Crawford proposed an innovation process comprising five stages with 67 specific activities whereas Cooper and Kleinschmidt (1991) suggested 13 different stages in the process. Besides that, Booz, Allen and Hamilton (1982) introduced an innovation model containing only seven activities to avoid confusion among respondents due to differences in terminology used [10]. While Jones in [8] recognised a model having three phases of innovation process referred as the inception (pre-development) phase, the creation (development) phase and the realisation (post-development) phase. Each phases composed of five different activities making the model having 15 activities all together with specific and identifiable output of each activities.

Cooper pointed out that there are different patterns of innovation processes exist [19]. They are either presented in linear or sequential, parallel or circular patterns. The early models of product innovation process are the linear models such as the first two models suggested by Saren [19]. Due to the limitations of the models for example little or no contact between the stages or activities and with the external parties and time consuming, parallel models has been introduced to overcome the weaknesses. For instance, a model of innovation introduced by Crawford portrays the parallel processes of technical, evaluative and planning activities as given in **Figure 6** [5]. The model has been recognised to permit the early detection of errors and speeding up the entire process. However, two problems were identified to be associated with the model: has no interaction with customers and suppliers and has no meeting point for the different functions to make decision.

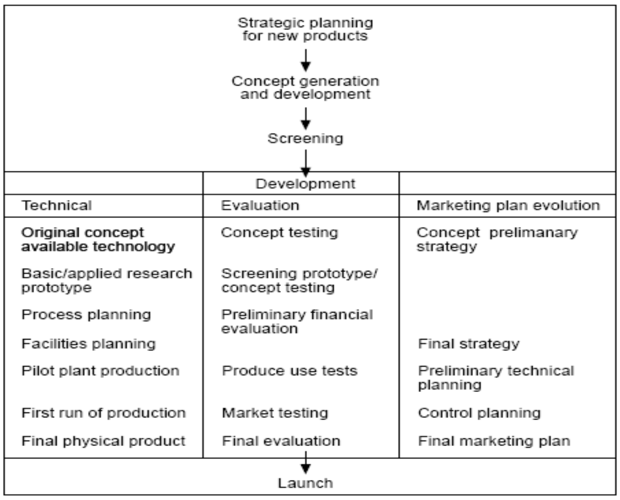

Figure 6: The parallel model of innovation process introduced by Crawford
Source: [5]

Another interesting model of innovation process is the circular model which consists of 26 elements developed by Buijs [19]. The model views the product innovation as a continuous process with no starting and ending point. It covers all the essential elements of the total process except for the elements of innovation organisation. The inside elements represent the internal aspects of the company, while the outside elements are related to the commercial and competitive aspects. The central elements show the core activities and results of innovation [19].

The above review demonstrated that there are different kinds of innovation model presented by previous researchers in various conception and composition. Each of them was trying to develop a model that best describes the innovation process according to the elements and factors that were considered to be significant to businesses.

4. KEY ELEMENTS OF SUCCESSFUL INNOVATION

Gardiner and Rothwell recognised the great affect of market needs and technological state of the art on the innovation process through the introduction of interactive model [20]. The view is supported by Cooper who developed a model of new product development showing the technical and marketing activities carried out complement each other within the firm, marketplace and the project [21].

However, Walker [11] indicated that there are three main factors of innovation: scientific and inventive ability (I), social and economic demands (D) and technological capabilities (T). Scientific and inventive ability relates to the individual creativity, scientific research, basic principles and initial engineering of prototypes, while social and economic demands have to do with the general social needs and market forces. Whereas technological capabilities refer to the resources, machines, labour and human skills. The three elements were expressed slightly different by Trott [12] as shown in **Figure 7**. He clarified that innovations are resulted from the interaction of new knowledge creation (science base), technological developments and the consumer needs. The relationship between these three elements forms the basis for the developments of today's innovation models.

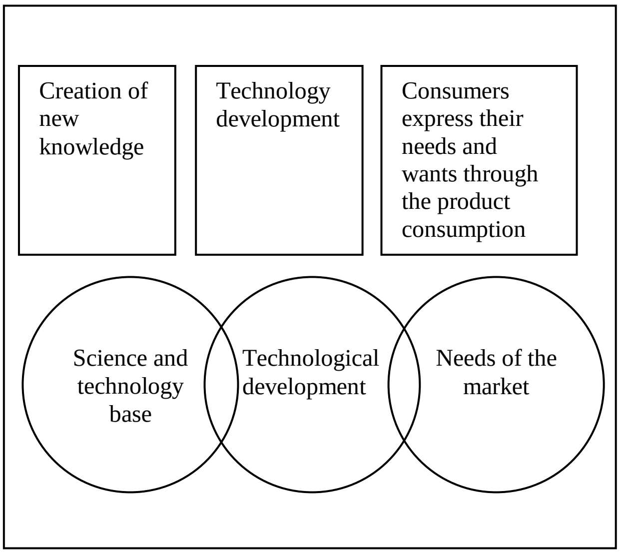

Figure 7: Elements of successful innovation
Source: [12]

The interactions of the three elements (i.e. idea, technology and demand) determine the successfulness of a product innovation [11, 12]. According to Walker [11], the absence of one or two of the elements will result in unsuccessful innovation called innovation prematurity (leap) and innovation delay (lag) as summarised in **Table 1** and illustrated in **Figure 8**. An innovation that is stimulated by the market demand with the absence of product idea and technological capability leads to the prematurity condition called demand leap. A demand lag condition occurs when an innovation is initiated by the creation of new knowledge and technological development without the customer demand. The product development will be postponed until sufficient demand is generated. In other words, product innovation cannot be implemented successfully without the existence of all the elements (i.e. (I + T + D)).

Table 1: Types of unsuccessful innovation

Condition	Type	Example
Prematurity	Idea Leap **I** -(**T** + **D**)	- Idea inappropriate to existing technology - Needs are latent and to be stimulated only by fully developed artefact
	Technology Leap **T** – (**I** + **D**)	- Technological devices well-known, but not theoretically based - Radical prototypes awaiting development into useful devices
	Demand Leap **D** – (**I** + **T**)	- Needs awaiting fulfilment in good invention - Ideas and technology inappropriate in responding to demand
Delay	Idea Lag (**T** + **D**) -**I**	- Lacking of inventive idea
	Technology Lag (**I** + **D**) - **T**	- Lacking of materials or manufacturing technology
	Demand Lag (**I** + **T**) - **D**	- Need not proven

Source: [11]

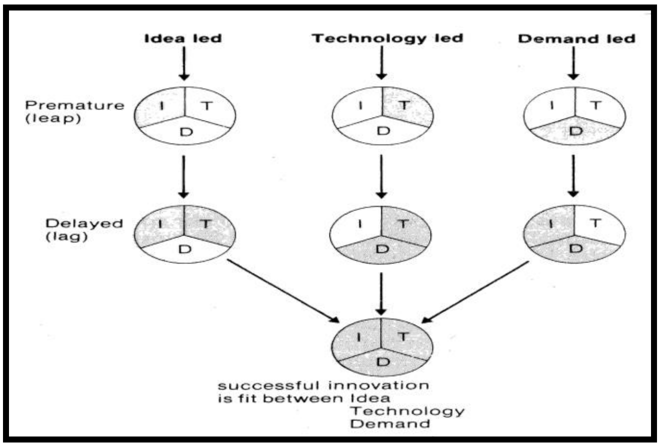

Figure 8: Prematurity and delay in the innovation process
Source: [11]

5.0 DEVELOPMENT OF AN ALTERNATIVE INNOVATION MODEL

The model of innovation process developed in this paper is portrayed in **Figure 9.** The model presents the innovation as a successive process consisting seven stages of activities. Innovation activities introduced by Ulrich and Eppinger in [13] and Booz, Allen and Hamilton in [5] have been combined to describe the stages carried out during the innovation process. According to the new model, the innovation process involves the following stages:

i) *Concept development*
It is a process of transforming the new product idea into identifiable product concepts. Multiple product concepts are produced and evaluated and the best concept is chosen for further developed. At this stage, the design feasibility, manufacturing feasibility and marketing feasibility are studied to determine its production and market potential.

ii) *Product design*
It is a process of producing the detail drawings of all parts that constitute the product together with tolerances, standards, materials and production process for producing them.

iii) *Prototype production*
It is a process of turning the detail designs into multiple physical model of product for testing.

iv) *Testing*
It is a process of evaluating the prototype to determine whether it can functions as required. The designs and production processes will be changed accordingly when needed to ensure that the product can perform the intended functions.

v) *Business analysis*
It is a process of assessing the business potential by analysing the sales, costs and profit projections. This includes implementing the market analysis, risk analysis and sensitivity analysis.

vi) *Production ramp-up*
It is a process of producing the product at full scale using the designed production system. The designs and production systems are monitored and amended gradually as to ensure the product is produced with the most optimal system.

vi) *Product launch*
It is a process of releasing the product to the market. This involves the making of key marketing decisions such as when, where, whom and how to launch the product.

The model is the reformulation and extension of the network model suggested by Trott [12] and Rothwell [16] and the coupling and integrated model presented by Rothwell [16]. The model shows the four main functions in the business which play important role in implementing the innovation process. They are represented by the research and development, engineering and manufacturing, marketing and sales, and finance departments. The feedback loops between the activities such as introduced in coupling method allow close interaction and intensive information exchanges among the different functions. This means that the other function's opinions and know how are considered throughout implementing the innovation process since they are interrelated to each other to ensure the successfulness of the process.

Besides that, the external linkages with the relevant entities in the business environment such as customers, suppliers and competitors permit the additional information flows into the new product development process and assist business to develop products that best meet the customers' needs. Timonen [13] regards the information flows from within and outside of the business as a process of accumulating the knowledge from various sources. She further described that the intra-organisation and inter-organisation integrations results in the building up of the knowledge over time as the innovation process progresses and therefore enhance the process.

The parallel feature of integrated model has also been adopted in this model by which few activities are carried out simultaneously to accelerate the innovation process. According to Rothwell [16], a certain degree of activities overlap with extensive information exchange is important and has proven to improve the Japanese companies' innovation process, but it is not possible to produce completely simultaneous development process. Hence, in this model several activities are overlap such as the concept development and product design. Apart from that, parts of the prototype testing and business analysis activities are also occur at the same time. This will contribute to shorten the product development cycle and assist businesses to become more innovative.

The most important part of the model is the production ramp-up stage whereby functional build (FB) approach to manufacturing validation has been adopted as one of the technology elements which can be applied to improve the innovation process. It has been introduced by Jay Baron in 1992 and used widely at the validation stage of product in the automotive industry such as General Motor and Chrysler companies especially to build the vehicle body [3, 22].

FB is a method of validating the individual components of assemblies based on the assembly specifications rather than on the part print specifications. The components that make up an assembly are accepted if the assembly is acceptable regardless of whether they meet the design specifications or not [22]. The parts evaluation is made in relation to other mating parts and assembly process and not only on their print specifications [23]. This allows the out-of-specification parts to be assembled provided that the final build (i.e. the assembly) meets its specifications and functions properly as customers are concern more on the quality of final products and not on the individual components which constitute the product [3, 23]. Hammett *et al* and Ward *et al* in [24] indicated that FB is a decision making aid for businesses in realising the customer perceived value of products. Thus, the focus of this approach is to satisfy the customer expectation of product's requirements by controlling the manufacturing process to ensure that the product is produced according to those requirements.

FB is applicable on complex assemblies where the component process is difficult to adjust and the components conformance to specifications is not critical, that is the non-conformance components do not affect the assembly or final build and its functionality [3, 25]. The benefits that businesses might enjoy from implementing FB include the ability to minimise many of the unnecessary non-value added rework activities during the validation process and therefore reduce the total system costs and production lead time with the acceptable quality of final products [3, 23, 24, 25, 26, 27].

Based on the above discussion, it is clear that FB is a useful tool to innovate a successful product that is by meeting the customers' requirements since they are the income generator for the business. According to **Figure 9**, customers always have certain expectations of product specifications (i.e. the Final Build Specifications (FBS)) when creating demands for the product such as in terms of exterior and interior design, features, functions and performance. Thus, design of a product is produced according to the requirements and portrayed in Product Design Specification (PDS) by designer which then used to guide the product manufacturing process. However, the process of transforming the resources (i.e. the production inputs) involves various processes and variables which can result in deviations and non-conformity of processes outputs to PDS. Therefore, FB can be applied to control the final product specifications by permitting certain extent of flexibility in relation to its compliance to design specifications throughout the processes of producing it. In other words, this approach to product validation allows the parts that make-up the product to deviate from their design specifications to some degree provided that the deviations do not affect the functionality and specifications of the product final build. In this case, PDS is treated as goal to be achieved at the end of the manufacturing process rather than total requirement that must be fulfilled during the process. The focus is on producing final product having the same or at least nearly the same specifications as required by customers.

6.0 CONCLUSION

It is true that product innovation is the determinant of businesses' survival in these days competitive environment. Businesses see innovation as an invaluable weapon to outperform their competitors and become the market leader. Innovation is a broad area of study and the process composes multiple phases or stages. Further research can be performed on other stages of the innovation process or the other area of innovation process. As an example, concurrent engineering and networking is becoming increasingly important in the innovation process since it can help businesses to become more innovative.

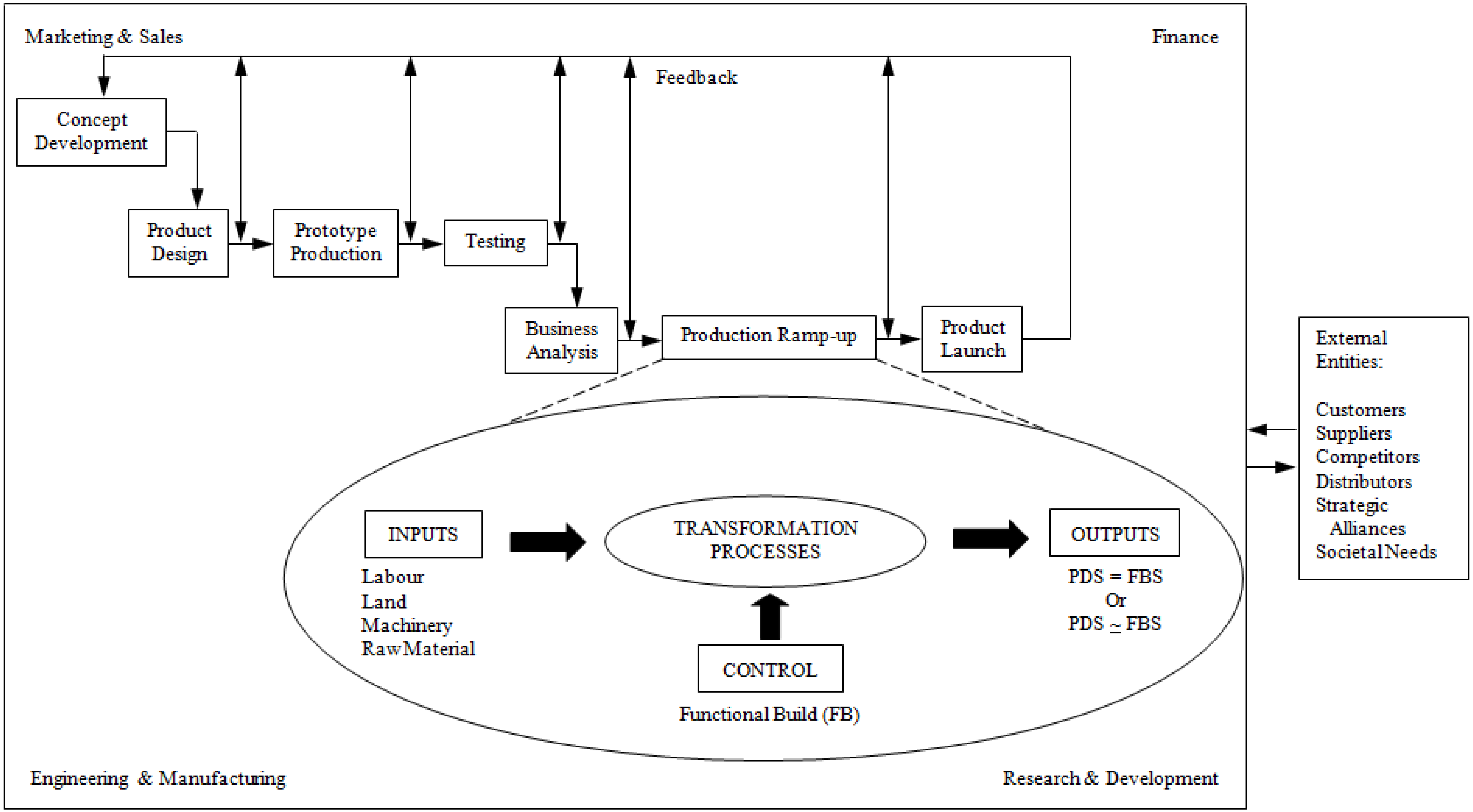

Figure 9: Alternative Model of Innovation Process

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