Chapter 3

MODELLING TECHNOLOGICAL INNOVATION

3 Introduction

This chapter touches on the discipline of modelling and then progresses towards developing a model for technological innovation. By modelling the innovation process, one might identify relationships and characteristics of the various functions and visually display them to the advantage of organisational management and staff.

As well as being an illustration of innovation processes and functions, a model may serve as a foundation for innovation auditing, without which poor audit implementation would result. A model serves as structure for the innovation audit, and by supplying the key areas of focus in the innovation process, the audit is able to target high impact areas. The holistic overview of the innovation process, provided by the model, therefore serves as guide to the innovation auditing process.

After the development of an innovation model to use in conjunction with an innovation audit, the chapter concludes with an example of adapting the proposed innovation model. The proposed generic model is adapted into several specific models, each representing aspects of the innovation process, tailored to the needs and requirements of an organisation. Such an 'organisation specific innovation model', is powerful in its representation of the interaction between elements of the innovation processes in the organisation. It may often be used as a benchmark or an action plan, for improving the organisation's innovation methodology.

3.1 The Importance of Modelling

Most successful managers have a clear sense of direction, as well as the ability to inspire others in this regard. When a typical new product development is started, it is usually accompanied by a business-plan, describing what the product will be, and how it will be produced. A business-plan however is not enough. Nor is it sufficient to improve the subsections of the business-plan to the finest detail.[1] No traditional business-plan can give an adequate overall representation of the direction of the business and its sub-functions. Thus, behind the successful development of a new venture, there should be a process that identifies and integrates the strategies and functions, and link them to the overall business strategy.

New projects need a method for planning, benchmarking and finding direction. In a project, this tool is often called a *project plan* or a *strategic model*. Not using a model to guide and represent milestones, destinations, areas of interest and areas of trouble, may lead to poor management and a disorganised workforce. Models give the opportunity of visually displaying the road ahead, while also showing the current position.

3.1.1 Functional Models and Maps

In every business and every function in the business, there are driving forces that define the critical dimensions of competition.[1] In the marketing of garden tools, for example, an important driving force may be the changing nature of distribution channels, as discount retailers and emerging superstores become the outlet of choice for customers. In the same business, the introduction of electronic control, plastic materials and powerful electric motors, may create product opportunities, that opens-up new segments in the market place. These market and technology drivers, place significant force on tool manufacturing processes, where traditional focus on cost reduction may be in conflict with the need for flexibility and expansion of variety.

Modelling has a clear objective:

> *It captures the driving forces for the process and elements, and portrays their implications for understanding in a graphic way.*[1]

Defined in these terms, functional models have the following distinguishable characteristics:

> *They are visual, graphic displays of the driving forces in the process, and the firm's position along critical dimensions of the model over time.*[1]

The very purpose of a model is to give managers a way to see the evolution of critical dimensions in the process, technology and market. Although good models are based on data and analysis, pulling together that analysis in a visual format, greatly enhances communication and the development of insight.

With a visual, graphic display of the critical dimensions of innovation, a business may collect a set of models that facilitate communication, focus attention, and provide historical context. What is missing, however, is a benchmark — a standard of comparison that creates perspective. Thus, the last requirement for an effective model is comparison with competitors. Finding out 'where we are' and 'where we are going' cannot be done only with internal data. The relevant standards are not past budgets or plans, but what the toughest competitors have accomplished.

Furthermore, seeing what competitors have done, may yield important insights into differences in competitive performance.

Models help to ensure that all functions share a collective vision of where they are going, and of how individual projects contribute to the common purpose. Moreover, modelling facilitates effective mobilisation of all the organisation's resources, capabilities, and skills. Models provide a tool for guiding the development of functional excellence, and they facilitate the strategic integration of that excellence around a common purpose. Additionally, models help an organisation to target its investments. By displaying underlying forces at work in the marketplace, models help to clarify choices firms face, regarding which markets to serve, with which products; which manufacturing facilities to employ; what process technologies to use; and what directions to take in the development of product designs.

Although several different innovation models are used in practice, this thesis will focus on technology based innovation models. The characteristics of these models are discussed in the following paragraphs. The proposed innovation model developed, through participation with industry and adaptation of current models, will be discussed thereafter.

3.2 Modelling Technological Innovation

Innovation is a complex and multi-faceted process, changing from application to implementation and process to product.[2] The complexity of innovation lies in the impact it has on every aspect of the organisation. Different types of innovations may range from improvements in base materials, to producing radical new products, to improving services marginally, and each of these may require different strategies, resources and implementation processes.

Focussing on technological innovation narrows the field down a bit and by focusing only on technology as the foundation for the new innovation, the diverse types of innovation may be reduced.

In this regard, this thesis will firstly consider a technological innovation as a *process* containing identifiable parts, and secondly, the impact the *environment* has on the innovation process. The *environment* refers to the *fostering* influences on the innovation process.

The part of technological innovation that may be regarded as a *process*, is possibly one of the more systematic and better-developed areas, as opposed to the *fostering environment*. It is similar to the new product development process, as well as the discipline of systems engineering. At its core it consists of three sequential concepts: *invention, realisation* and *implementation*. These three concepts are the elements most definitions of innovation refer to, when they explain the process of technological innovation.[See chapter 2, Girifalco,[3] Berry & Taggart,[4] and Roberts.[5]]

The *fostering environment*, which forms the second part of the innovation process, is not such a precise or systematic science as the *process* side. This, as well as the limited reference made to this side of innovation in classical definitions of innovation, result in few innovation models actively including the subject in their representations.

Although research by Foster[6], highlighted the importance of the fostering environment, little has been done to actively develop the subject. This, as well as the breadth of the field has conspired against innovation modellers incorporating the fostering environment in their innovation models, leading to the poor state in which innovation models represent the fostering environment.

In this thesis the well travelled road of defining innovation as a process and conveniently forgetting the required fostering environment, will not be followed. By combining both the areas, *process* and *fostering environment* into a single model, this thesis is able to construct a holistic image of technological innovation. Enabling key linkages and interactions to be visually displayed, and improving the comprehension and understandability of the structure of the discipline of innovation.

Although modelling technological innovation as a two-part process, as just proposed, has certain advantages, other models do not necessarily follow this path as boldly, nor do they necessarily model the process in the same way. To ensure the proposal made above is valid and accurate, three viewpoints, where different models are reviewed and their advantages and disadvantages listed, will be elaborated on forthwith. These viewpoints are *linear* vs. *non-linear* modelling, model *representation* level (hierarchical implementation depth), and *generic* vs. *organisation specific* modelling.

3.2.1 Three Modelling Viewpoints

In any model or map, certain viewpoints of the author, and his/her ways of understanding of the subject, shimmers through. This is exactly the case with current models in the technological innovation field. The nature of the innovation process is complex and therefore each person makes his/her own conclusions. This gives rise to many different angles on a single process, each having its own advantages/disadvantages as specified by the model's author.

The following three viewpoints were chosen to represent the many different ones in practise. They are not necessarily exhaustive but should hopefully represent the various viewpoints clearly. The three viewpoints include the following.

- *linear vs. non-linear* models
- *hierarchical depth of implementation* models
- *generic* vs. *organisation specific* models

These three fields will be discussed in detail in the following sections, and may include different types of models such as elemental models, strategic models, generic models, organisation specific models, and type of innovation models.

3.2.2 Linear versus Non-linear Models

Through the study of innovation models, the diverse nature of the field becomes apparent. *Linearity* and *non-linearity* surface as one possible answer to complexity. Currently almost all innovation models are linear, and therefore a conceptual nonlinear / 3-dimensional / multi-dimensional model was researched. This entails computer-generated graphics and the possibility of constructing a generic model, representing many different aspects of the innovation process.

This modelling method would have several advantages above linear models. One of the most important, is better representation of connections between functions in the innovation process. This would enable the modeller to connect functions to each other, through a matrix in three dimensions, and measure the impact each element in the innovation process has on all the others. The innovation process would finally be represented by a 3-dimensional form floating in space, containing every possible interaction between functions and elements of the innovation process.

More detail and examples on linearity and non-linearity are examined below:

3.2.2.1 Linearity

Almost all the innovation models studied as part of the literature review for this thesis, contained a measure of linearity. Causality also plays a big role in the representation of innovation elements. As innovation elements have clear inputs and outputs, they lean themselves towards inclusion into an element or causal model.

The elements and routines of technological innovation can be compared to the new product development process. Although many different types of technological innovation occur, the new product development structure helps to identify the correct elements in the innovation process to model. New product development can be represented as a funnel, where new ideas flow from the market or technological environment, through stage gates and development procedures, into the manufacturing and marketing phases. The funnel is represented as linear, and so the process of new product development is also represented as linear. The funnel,[1] as illustrated in the addendum [Appendix D], of new product development, can be used to represent the elements, and routines in the process of technological innovation. In this regard, new product development and technological product innovation, is very similar. Another linear development process may be found in the discipline of systems engineering.[7] The process starts with the definition of a need, progresses through the various stages of design and ends with product phase-out and disposal.

Noori[8] illustrates a good example of a basic linear innovation model. As Noori explains the process of modelling technological innovation, he refers to two basic linear innovation models. One being, technology *push* innovation, and the other market *pull*.

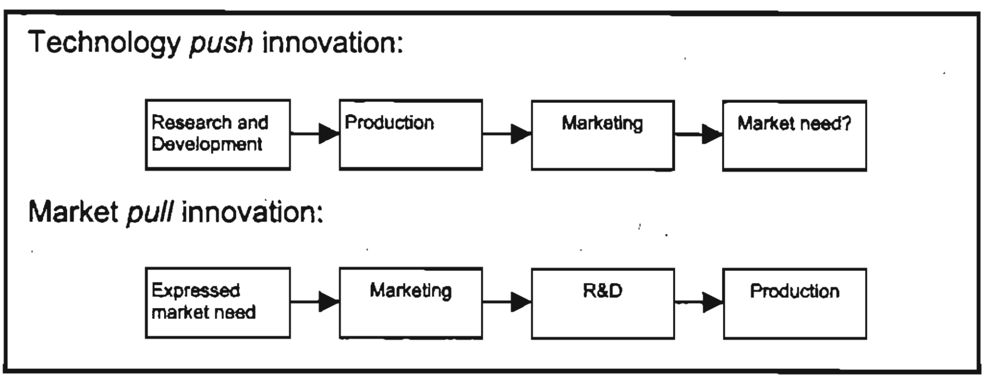


Figure 3.1: Linear Innovation Models, adapted from Noori[8]

The Noori models are examples of two different types of innovation. In their simplicity, they do not refer to any other external influences on the innovation process, other than inputs and outputs for each element. If however all the other facets of the innovation process were included in the Noori models, they would not be linear any more.

Other innovation models were found to exhibit measures of linearity as well. Examples of models by Twiss,[9] Utterback,[10] Tidd *et al*,[11] Marquis,[12] Katz[13] and Thamhain[14] are included in the addendum [Appendix D]. These models are only given as examples and not as an exhaustive list of linear models. They therefore serve the purpose of illustrating the concept of linearity.

Linear models list every element in the innovation process sequentially, as they follow upon each other in the process. The advantage in this is the simplicity and ease of understanding of the model. Making it suitable to be implemented in environments where knowledge of innovation is limited.

The negative aspects of linear models do however outweigh their advantages. The innovation process is simply too complex to be illustrated with a linear model. Innovation consists of many levels where processes run in parallel or even in recurring loops. Although some linear innovation models compensate for the complexity, by using branches and feedback loops, these are often added as an afterthought and seldom occur in the same way in practise. Some of the limitations and advantages of linear models are:

The following *advantages* of using linear models exist:

- Understandability
- Ease of implementation
- Clear expression of causality

Disadvantages of using linear models:

- Poor representation of required competencies
- Highly specific
- Rigid, and often causal
- Poor representation of multi-faceted aspects of innovation
- Poor representation of links between the different facets of innovation

Linear models attempt to indicate the structure of innovation in a causal fashion. By illustrating the inputs and outputs of different innovation elements, they attempt to create a logical path or recipe to follow when innovating. However the multi-faceted nature of innovation does not lean itself towards such a process, if at all. By disregarding the notion of creating a causal innovation model, new avenues of exploration may appear to the modeller.

The only true representation of the innovation process might therefore be through a higher order model. This refers to a model in three or more dimensions. The advantage of such a model lies in its interconnectivity. Each element is in contact with many other elements of the innovation process. As such, valuable synergies are accomplished, and thus a higher order of innovation becomes possible.

3.2.2.2 Non-linearity

Technological innovation does not as a rule follow a neat path, where elements succeed each other, predictably or logically. This is precisely why multi-dimensional models become necessary for representing the process. The advantage of multi-dimensional models lie in their ability to represent processes more holistically than linear models. Interesting examples of multi-dimensional models may be found on the World Wide Web at www.doblin.com,[15] illustrating the viability of seeing innovation as a multi-dimensional process.

Representing innovation as a non-linear multi-dimensional process is not easily accomplished. Many factors directly influence every aspect of the innovation process, and representing each of these influences, can wreak havoc on linear type models.

In this thesis a three dimensional model representing three basic areas (*resources, type of innovation* and *market needs and demands*), that form part of the technological innovation process, is proposed. It should be noted that the three areas are not the only areas and many others may also be used successfully.

In the model, three axes are displayed (*resources*, *type of Innovation* and *market needs and demands*). Each of these represents a facet of innovation, and has direct influences on many aspects of the other two. Although highly conceptual, by modelling innovation in this way, the diverse nature of organisations and their own innovation procedures, can all be accommodated. Figure 3.2 illustrates this model.

To practically use the proposed model it may be used in its three dimensional form, or alternatively by slicing through the model to form an exposed plane, such as illustrated in Figure 3.3, a more specific model may be created. In concept the visible plane should represent a certain innovation methodology in a two-dimensional format, in the liking of the previously illustrated linear innovation models. The proposed three dimensional model contains an infinite number of these planes which may be sliced to illustrate new methodologies for new innovation purposes. An example might illustrate the implementation of the model better.

> For instance:
>
> An organisation might be involved in a stable market, with a well-defined dominant design and be constantly busy with stable incremental innovation to sustain their competitive advantage. The methodology for this type of innovation (sustaining and incremental) would however be different from a methodology for attacking or radical innovation.
>
> Therefore if a sudden change occurred in the stable market such as a paradigm shift, the organisation might have a number of options. It might defend its products by price cutting or better marketing. Alternatively it might consider changing its innovation methodology and becoming more aggressive or radical. If the organisation previously modelled its innovation process as well as its capabilities in the form of a three-dimensional innovation model they might respond in the following manner.
>
> By slicing their three-dimensional innovation model at a different angle they might expose their attacking or radical innovation methodology (linear-model). Thereby transforming the current innovation methodology from sustaining to radical. This model may then help them to innovate more aggressively and catch up or dominate the sudden changes in the market environment.

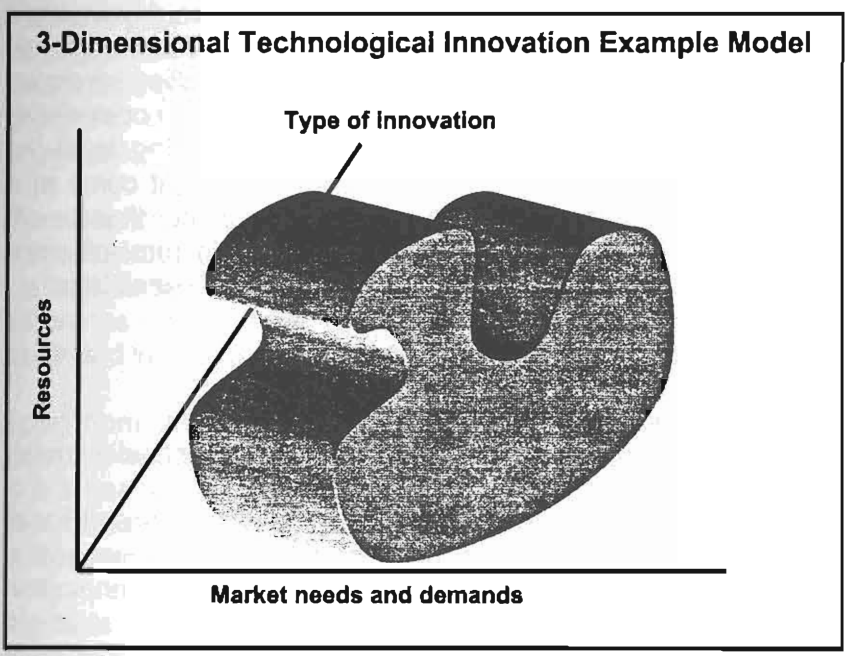


Figure 3.2: Proposed 3-D Technological Innovation Model

Although the power of the above mentioned multi-dimensional modelling process is clear, modelling the total technological innovation process, is not so easily accomplished. Three axes are shown in the above example, but many more exist. A myriad of three-dimensional models will therefore have to be constructed to facilitate the representation of the total innovation process. This seems impractical as well as somewhat insensible.

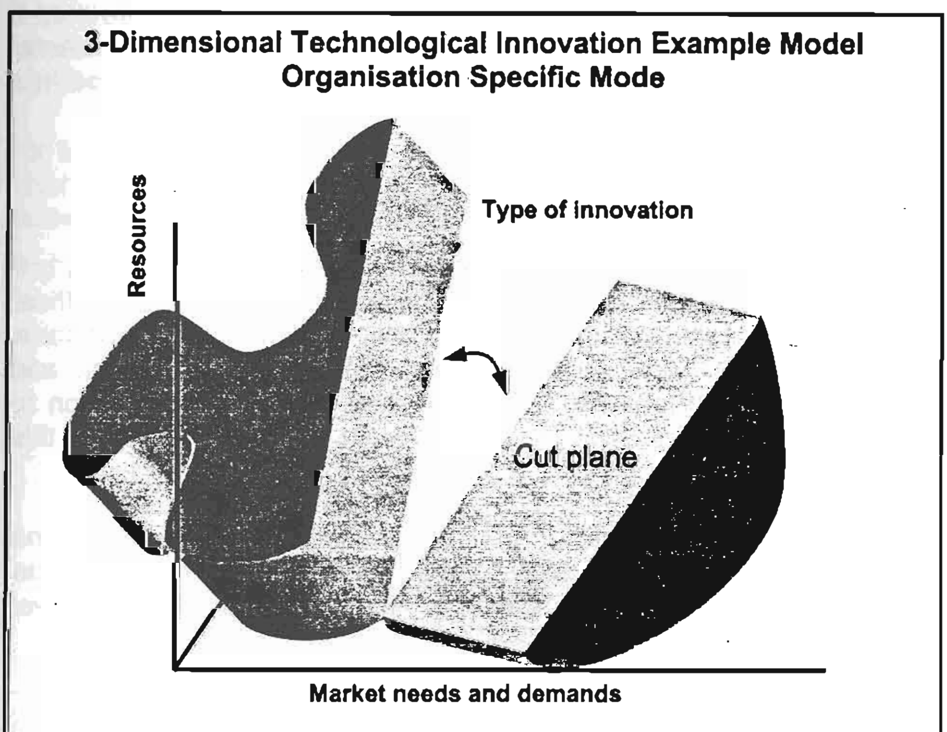


Figure 3.3: Proposed 3-D Technological Innovation Model in Organisational Specific Model

The three dimensional modelling of innovation may be augmented into developing a N-dimensional model. Such a model would have 'N' number of different axes and therefore solving the conundrum of the three-dimensional modelling process. Although highly academic as well as possibly impractical there is merit in considering the process of modelling innovation in this manner. Through struggling to fit the multiple pieces of the innovation process into such a model one might come to a better understanding of the inter relations, and the causes and effects these multi faceted parts of innovation may have on one another. This may in turn influence one's ability to represent the innovation process in a more accurate or sensible way.

The following *advantages* for multi dimensional modelling exist:

- High information content
- Strong interconnectivity between elements
- The total innovation process can be modelled (one model includes many different types of innovation)
- By slicing the three dimensional model and implementing the exposed linear model different innovation methodologies might be pursued by means of a single model. This has the advantage of calibrating all the innovation methodologies followed by the organisation, in turn improving the strategic innovation competence of the organisation.

Disadvantages for multi dimensional modelling:

- Difficult to model completely
- Difficult to understand the model without assistance
- Very complex

Complex problems have a way of being represented as non-linear multi-dimensional processes. This tendency of modellers to over complicate things, can inhibit the usefulness of models. In such cases, the modeller is often the only person who understands the model completely, as well as the reason why it looks the way it does. This makes non-linear models unfavourable ways of representing systems, even if the systems they are supposed to represent should ideally be modelled in a multi-dimensional way.

3.2.2.3 Conclusion to Linear versus Non-linear Models

The conclusion as to which to use, *linear* or *non-linear* is not a trivial task. Clearly if the process to be modelled is causal and finite, linear modelling would suffice. However, innovation is not causal and neither is it finite, leading to the conclusion that multi-dimensional models might be the answer. Finding a middle road and incorporating aspects of linearity and multi-dimensionality, may offer a solution to innovation modelling. This will be explored in the proposed model later in this chapter.

The following viewpoint on the modelling of technological innovation, discusses the hierarchical depth of modelling. It is one of the three key areas of modelling, as mentioned before, which includes *linear* vs. *non-linear* modelling, *representation level* (implementation depth), and *generic* vs. *organisation specific* modelling.

3.2.3 Hierarchical Depth of Innovation Models

Although the representation-level (the part of the technological innovation process represented) of a model has little to do with the actual technological innovation process, it has a lot to do with who will be reading and interpreting the model.

Different people need different information from different models. For instance, a strategic manager would not find a model describing a functional process useful. A model with goals and deadlines and strategic implications might be more to his/her liking. For these reasons, models need to be developed for specific areas in the organisation, pertaining to which hierarchical level they are implemented on.

For simplicity, three hierarchical levels are defined, each with its own distinct characteristics and implications for the innovation process. The first level could be named the *strategic* level, and is possibly the most important, as it has far ranging influences on the other two. They are the *management* and *disciplinary* levels as illustrated in Figure 3.4.

Apart from the levels within the organisation, several others exist outside it. The industry, national and global environments are but a few of these. Each of these levels has an influence on the organisation, and how it operates. Inside the levels there are rules and routines. When an innovation model is designed it is best to try and keep inside these hierarchical levels, to avoid confusion.

The crossing of levels is often done when a generic innovation model is designed. Such models often confuse, and are only truly understood by a very select group. Although the reason for constructing such a model is to cover the total innovation process, it seldom reaches this goal. An example of such a model may be found in the work by Edosomwan[16] as illustrated in Figure 3.5.

The model contains aspects such as *policy formulation, problem solving*, and *resource balancing*, which each represents a different level in the organisation's hierarchy.

The model might be proposed for middle management, yet it offers tasks relating to strategic and disciplinary action. It therefore has to be presented to strategic, as well as disciplinary teams, which may find the model difficult to understand, since it contains so many aspects foreign to their expertise.

For this reason, Figure 3.4 is proposed. Three basic hierarchical levels are defined which may clearly be seen to illustrate where some of the previously discussed models would fit in. Some of the models yet to be discussed are included as well.

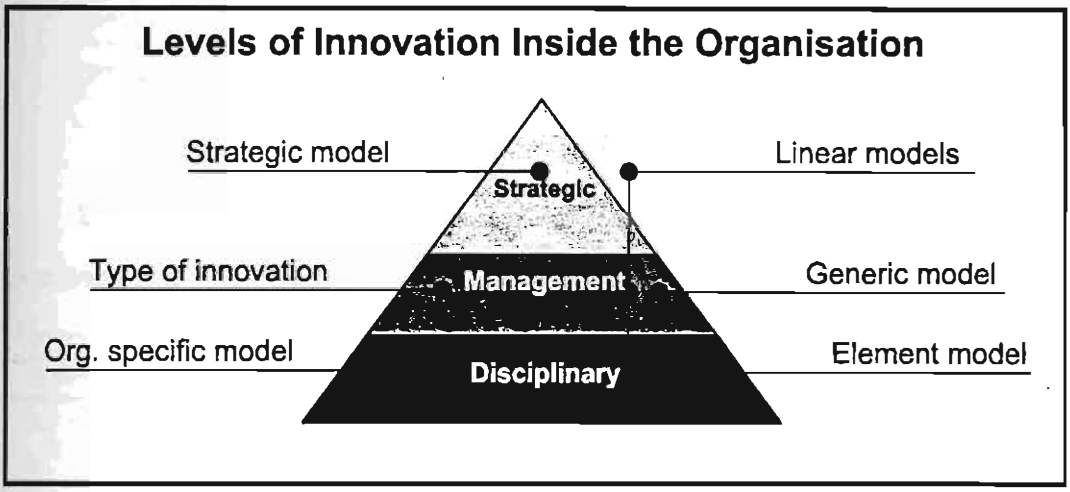


Figure 3.4: Levels of Innovation inside the Organisation

The figure illustrates where the different models find their best application. Since many of the models may be configured extensively, the figure is only meant for illustrative purposes. Many models cut across the levels to utilise certain aspects from other levels.

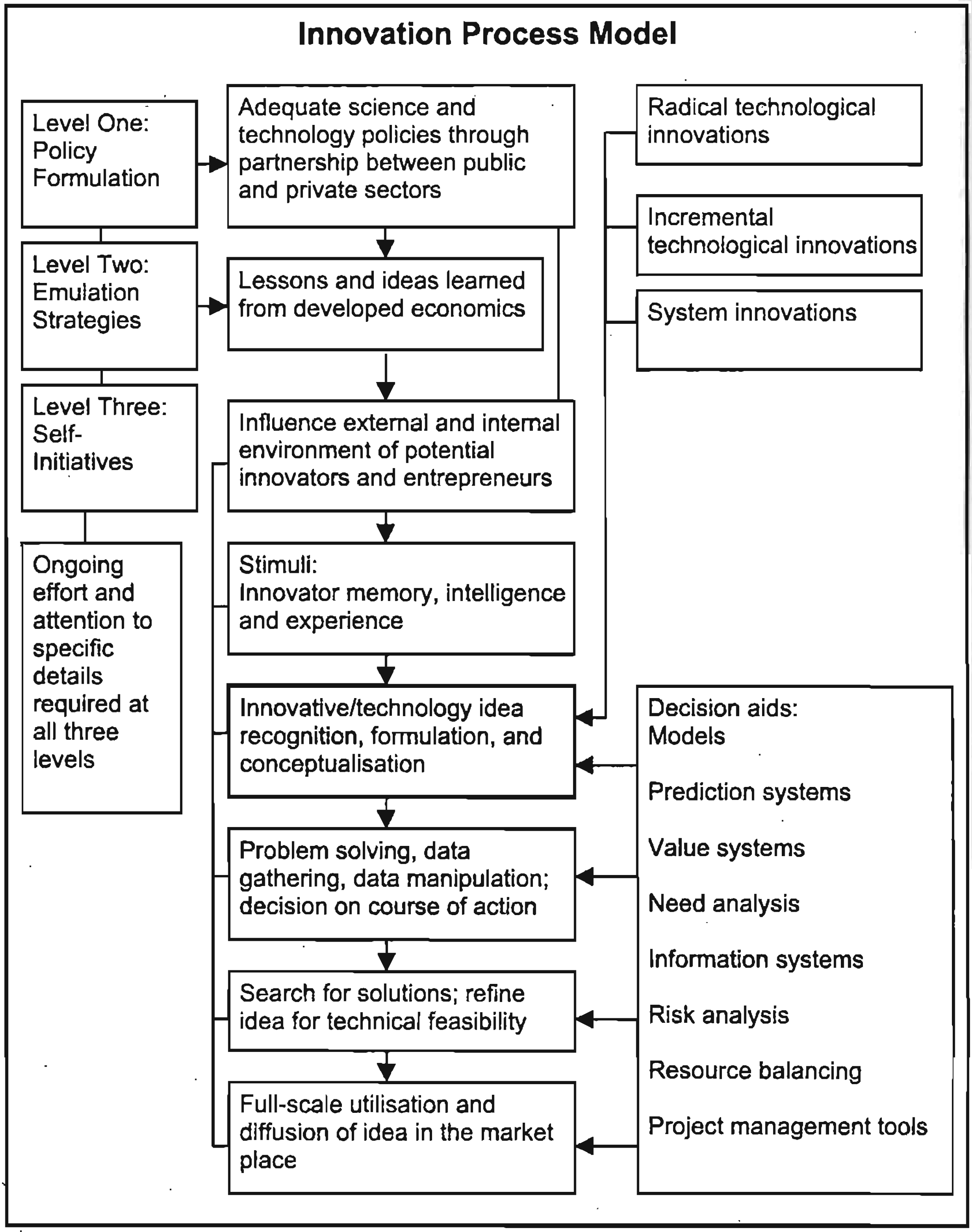


Figure 3.5: Innovation Process Model, adapted from Edosomwan[16]

The model by Twiss,[17] as illustrated by Figure 3.10, incorporates some management aspects, such as project champions, project management, knowledge of market needs, and scientific and technological knowledge, yet he also uses elements from the disciplinary level, such as R&D, production, design and marketing. Although these two levels seem to work well together, the model is difficult to apply in any of the two levels, for it excludes a lot of aspects particular to any one level. For instance, in the managerial level, aspects such as resources, tools and systems, information and many others are simply not addressed.

Although the aim is not to discredit the model by Edosomwan,[16] it is important to ask who will ultimately use the model, and how it should be adapted or constructed to best suit that individual.

3.2.3.1 The Element Model

The element model is one of the most understandable types of models. It often consists of a checklist of things to do, and or how to do them. To model technological innovation in this way, the boundaries of the model have to be defined very strictly. Will it cover just product innovation or technological innovation, or should it also cover general innovation? To define these boundaries, the interrelations between the elements, may be used. It should however be clear that a certain amount of data would always have to be excluded, to limit the complexity and maintain focus.

An element innovation model contain direct instructions on the required actions in the life cycle of the innovation. The model by Tidd *et al* may be regarded as a element model to a large extent, since it lists the underlying routines in the management of innovation.

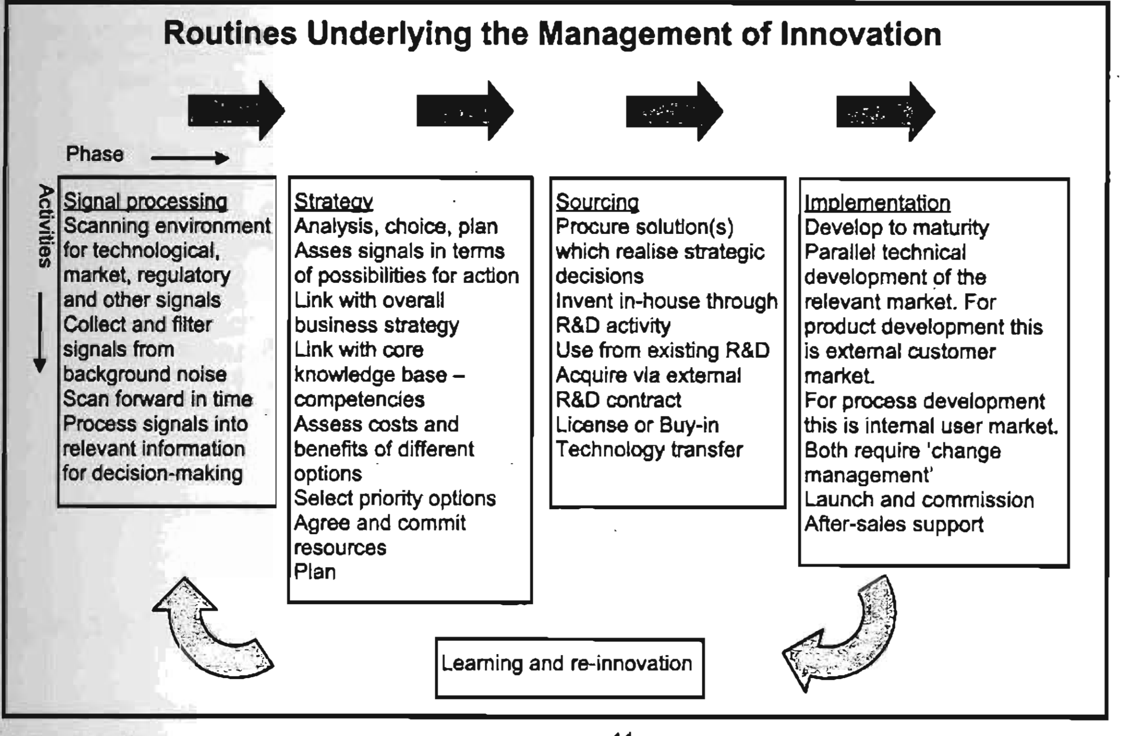


Figure 3.6: Innovation Model, Source: Tidd et al[11]

For instance a segment of the model illustrated in Figure 3.6, as proposed by Tidd *et al*[11] contains the following:

- Signal processing
- Scanning environment for technological, market, regulatory and other signals
- Collect and filter signals from background noise

- Scan forward in time
- Process signals into relevant information for decision-making

When implemented, these elements have a direct influence on the innovation process, and can sometimes even be used as a checklist. This is what gives element models their power, and why they can be very useful. When an inexperienced innovator is trying to learn the process of innovation, such a model might prove useful.

A good example of an element-based model, is a mind-map. These models are widely used by educators to help in teaching children to remember and summarise large amounts of data.[18] It works surprisingly well, since connections in the brain are more easily made, than when the information is simply listed.

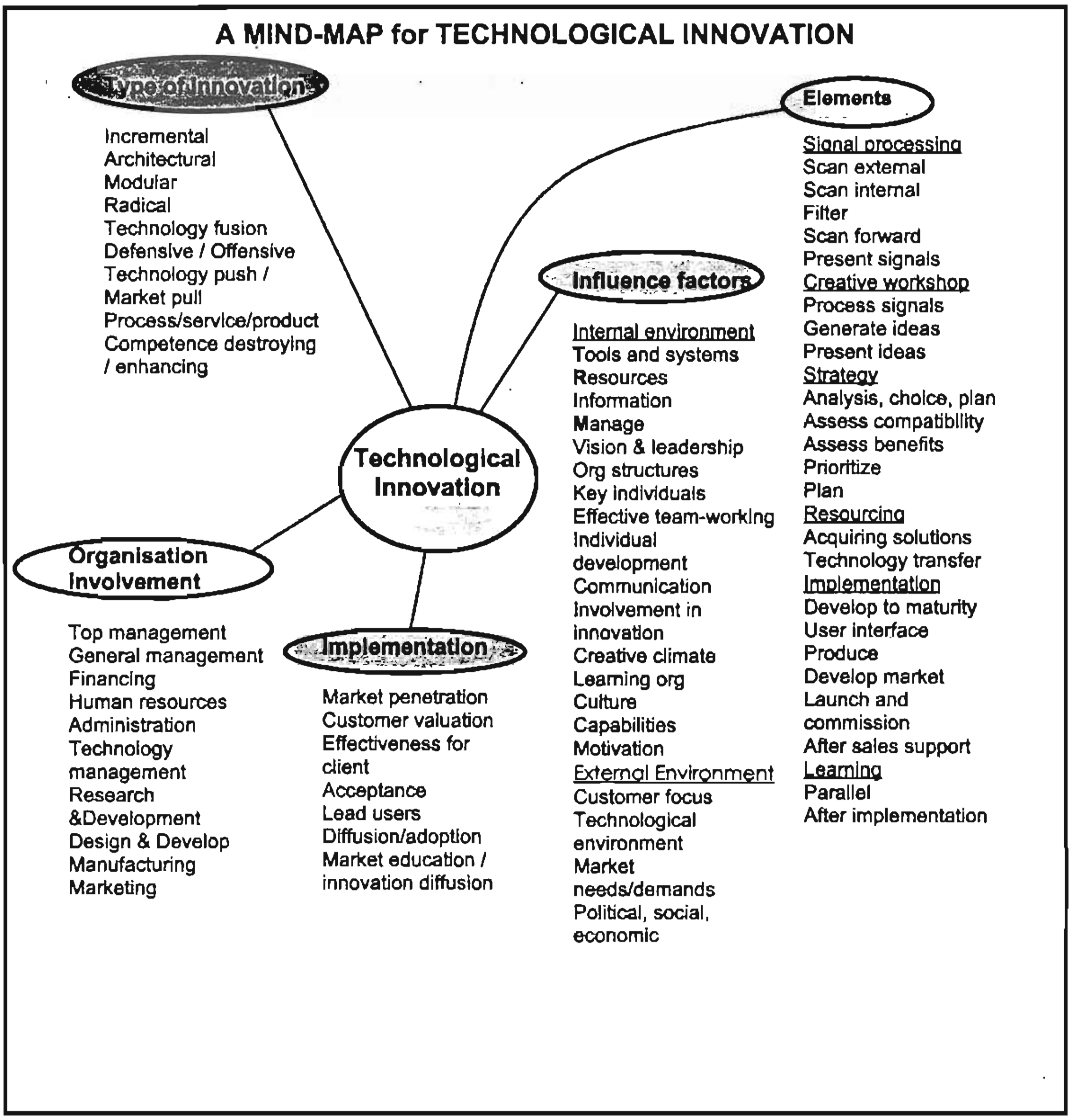


Figure 3.7: A Proposed Mind-Map Detailing Technological Innovation

In the quest for understanding technological innovation better, a proposed element model was developed, as shown in Figure 3.7.

Although a mind-map represents information well, it does not really qualify as an innovation model. To construct a model, the mind-map is used as medium for organising the information, before entering it into the final model. The nature of the mind-map ensures that the central aspects of the information are identified, and also the linkages with others. These central ideas or aspects can then become the main areas of focus in an innovation model.

The biggest negative aspect of element models sprout directly from their high focus. When focusing on a single type of innovation, for instance product innovation, the elements apply directly to the process, yet when another type of innovation, such as a service innovation is pursued, the model fails to instruct the user and can lead to poor conclusions or actions. Thus extreme care needs to be taken when constructing element innovation models. And they should not be used to represent a generic method for innovation.

3.2.3.2 Strategic Innovation Models

To manage the technological innovation process in an organisation, certain strategic choices need to be made regarding goals, objectives, and avenues of implementation. Although these are not addressed in an innovation model, displaying the correct information for making these decisions can. Factors such as technological strategy, economic impact on new developments or types of innovation, all have a direct influence on the strategic direction of the organisation. A good illustration of a model beneficial to strategy formulation, can be found in the work done by Voss at the London Business School.[19]

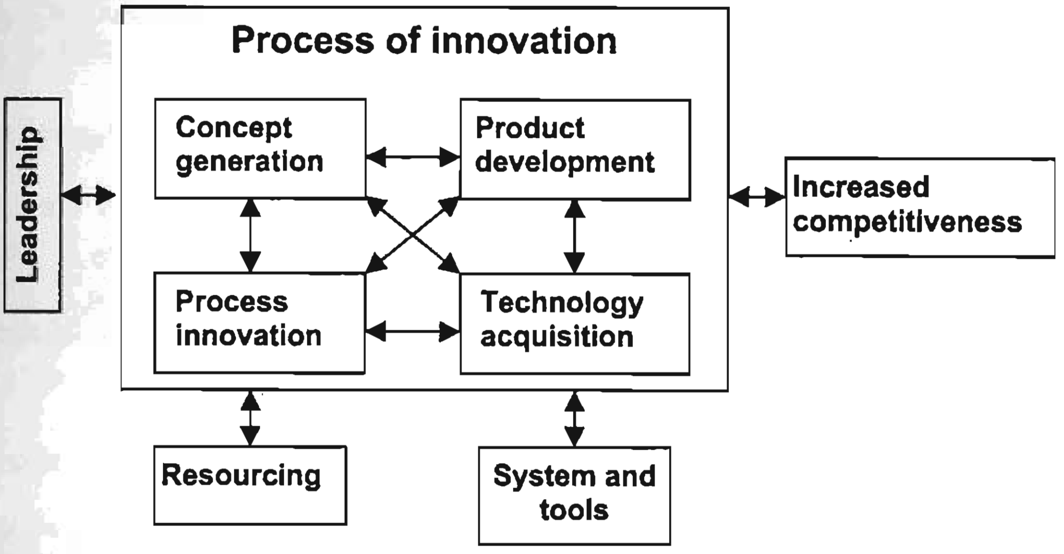


Figure 3.8: Technological Innovation Model adapted from Voss[19]

The model, illustrated in Figure 3.8, was developed in conjunction with an innovation audit, and the authors identified two areas of interest: the *enabling* processes and the *core* processes; of which the enabling processes are outside the 'Process of Innovation' rectangle and the core processes inside. Voss proposes that the enabling processes have the greatest significance for strategy formulation, for they influence the innovation process, and need to be linked to the main organisational strategy for optimum functionality. The model indicates the significance of these enabling technologies, and the role they play in the innovation process. This model is discussed in greater detail in chapter four.

The aim of a strategic innovation model is to include innovation in the organisational strategy formulation process, and highlight the innovation aspects of importance. Due to its hierarchical level, it might almost be possible to develop a model focussing specifically on integrating innovation and strategy formulation. This would improve executive management's ability to develop sensible organisational strategies with good innovation related content.

Few strategic innovation models that focus specifically on integrating technological innovation into organisational strategy is available. Although the previously listed models by Twiss[9], Utterback[10] and Edosomwan[16] have some strategic content, they do not devote large amounts of research to the subject. It might therefore be concluded that strategic innovation integration is either unimportant or has yet to be developed into a discipline where modelling is judicious.

3.2.3.3 Models Portraying Different Types of Innovation

There are many different types of technological innovation, with various applications and implementation methodologies. Few models have been found to actively differentiate between types of innovation piquing ones interest as to the reasons why. Since different types of innovation such as incremental, modular, radical architectural and others, require different strategies and implementation mechanisms, it is expected that innovation models would focus on certain types of innovation, rather than aiming to represent the whole spectrum.

For illustrative purposes the following types of innovations were identified.

- Radical vs. architectural vs. modular vs. incremental innovation[20]
- Competence enhancing vs. competence destroying innovation
- Technology push vs. market pull innovation[8]
- Process vs. product innovation vs. procedure[33]
- Offensive vs. defensive innovation
- Sustaining vs. disruptive[21]

To illustrate the point of incorporating different types of innovation into an innovation model, a possible example by Schumann *et al*[33] is considered. The model is not strictly a model, but rather a framework for innovation, since its main purpose is to serve as structure for a proposed innovation audit.

	Class		
Nature	Incremental	Distinctive	Breakthrough
Product			
Process			
Procedure			

Table 1: Class and Nature of Technological Innovation adapted form Schumann[33]

The different types of innovation in this matrix include incremental, distinctive, and breakthrough innovation.

> The **class** of the innovation refers to the degree of creativity or newness of the innovation, where incremental is only slightly different, and breakthrough is radically different.
>
> On the other hand the **nature** of innovation refers to where in the organisation the innovation will be carried out, and which field or process it will influence mostly.
>
> All in all the innovation model represents nine types of innovation, each requiring different resources, management skills, and markets strategies.

Although this model can supply some structure to different types of innovation questions, it can not instruct the user where and when to use the different types of innovation. This model is therefore best for identifying the underlining strategies used in the past by the organisation, and giving insight as to possible new strategies to be considered.

It would be interesting to know why the authors did not include other innovation types in their model, since the two fields, *class* and *nature* are certainly not the only types of innovation.

Although a strong case could be made for including different types of innovation into an innovation model, it is often impractical. The highly specific nature of the types of innovation is best left to the application of the innovation model. The aim of an innovation model is not to prescribe to organisations how to innovate, but serve as holistic example which integrates the multi-faceted aspects of the innovation process.

3.2.3.4 Conclusion to Hierarchical Depth of Innovation Models

A tight rope balancing act is necessary when developing an innovation model. Deciding on the level of implementation, only serves to increase the difficulty of deciding on a method for such a model. It is crucial to develop the innovation model for the right audience and ensure their ability in understanding and implementing the example set by the model. In deciding between strategic and disciplinary innovation models, the needs of the recipients has to be remembered and finally delivered upon.

3.2.4 Generic versus Specific Models

Many of the models reviewed throughout the literature study were generic, yet some clearly represented organisation specific processes, disciplines or methods. The best reason for modelling the technological innovation process as a generic process, is model implementability. Given most innovations' diversity, models need to include as many aspects of the process as possible, making the model applicable to a wide spectrum of situations. The disadvantage of this is that the model becomes more generic, and thus less definite in application. In other words, generic models require interpretation, and is therefore unable to dictate to the organisation how it should innovate. On the other hand, while specific models may dictate methods best suited to innovation, they are only applicable in very select circumstances.

To illustrate some detail on generic and specific models, the following two sections were developed.

3.2.4.1 Organisation Specific Models

Organisation specific models can offer great advantages over generic models, for they are designed to enhance a specific process, and can accurately model specifics, rather than trends or perceptions. The strength of such a model lies in its ability to represent the innovation environment, as well as current organisational routines and structures in operation precisely. Another advantage is the familiarity of specific models. Since the elements used in the specific model occurs within the organisation's structures and procedures, it is familiar to the employees and may find faster application. Specific models might therefore be more applicable to immediate organisational needs and not seen as 'pie in the sky', but as relevant to every step in the innovation process.

A possible example would be a model developed by Ross,[22] as illustrated in Figure 3.9. The model focuses on the strategic side of innovation, but has some specific characteristics Debtek (a division of DeBeers) finds useful.

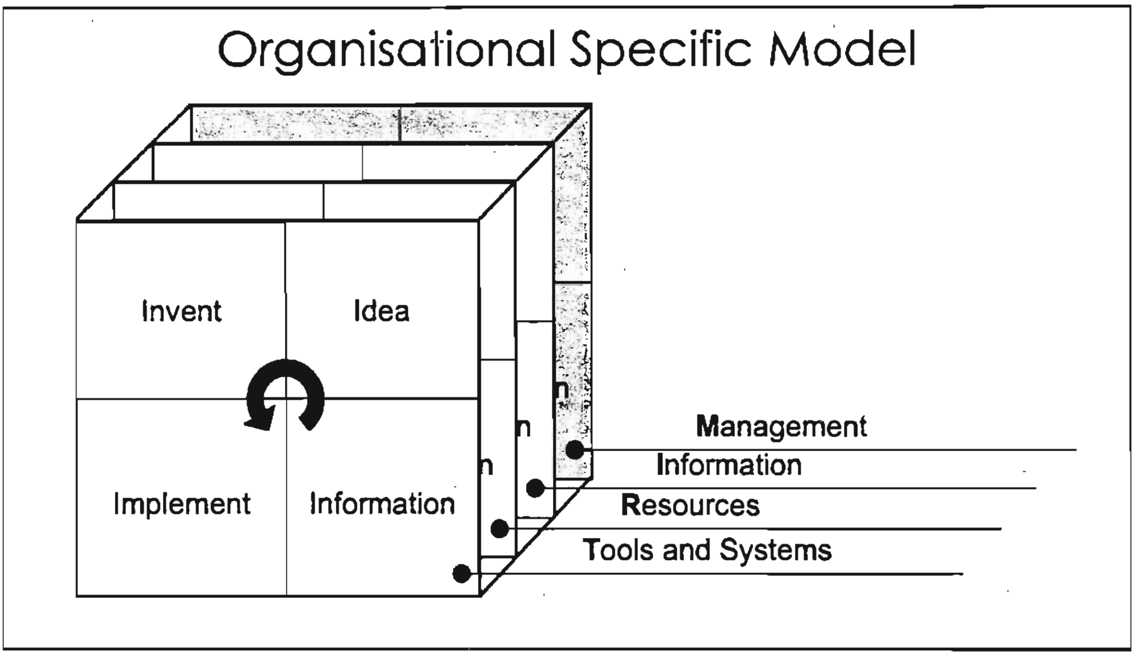


Figure 3.9: Organisational Specific Model, proposed by Ross[22]

The model proposed by Ross, although quite generic, describes the areas of particular importance to Debtek, and may therefore be easier to apply than other generic models. By working in conjunction with organisations, innovation modellers may find better application of their proposed models, as well as acceptance in the organisation. This is possibly one of the biggest advantages of specific innovation models.

3.2.4.2 Generic Models

The nature of the innovation process and its diversity, encourages modellers to work either highly specific, or very generic. The difficulty lies in the fact that specific models often find themselves excluding such a large proportion of the total process, that they lose sight of new developments, and become very rigid. However by designing generic models with scalable attributes, the conundrum may be solved.

Some good examples of generic models exist, of which models by Utterback,[10] Twiss,[9] Edosomwan[16] and many other innovation specialists form part. As an example, the model by Twiss is quite relevant, as illustrated in Figure 3.10.

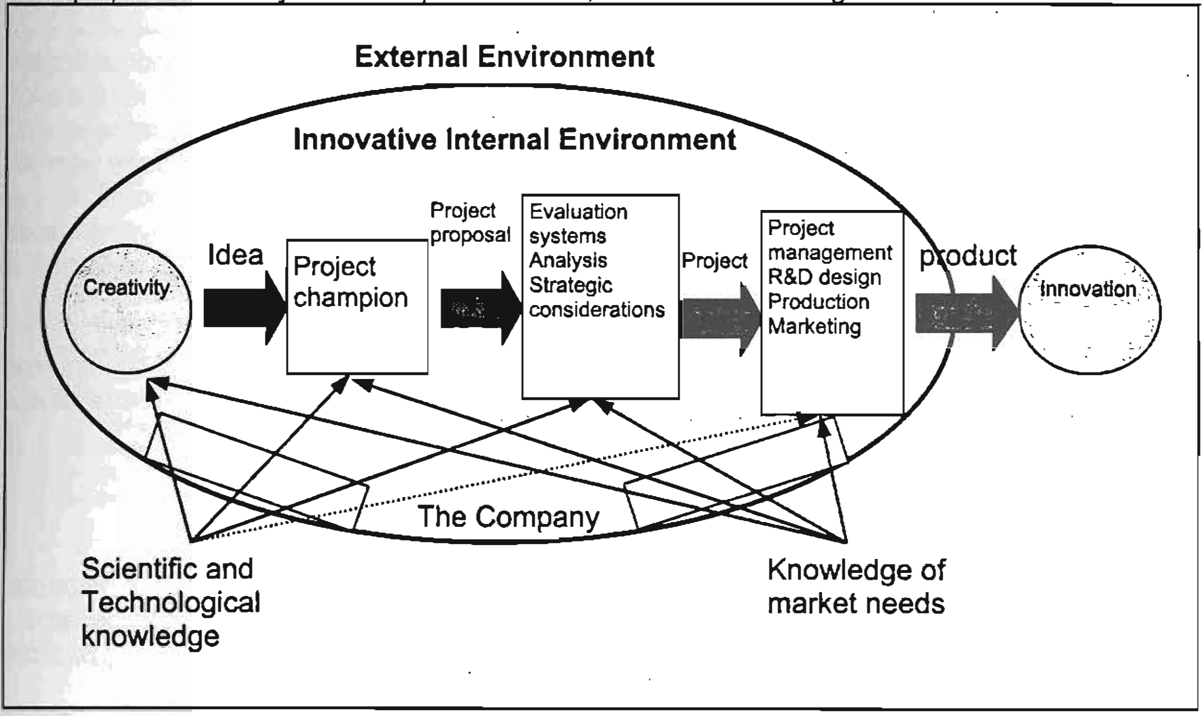


Figure 3.10: Innovation Model, adapted from Twiss[9]

The Twiss model is successful at capturing critical parts of the innovation process, while displaying several of the so called *fostering environmental* elements as well. The clear identification of creativity (first dark circle), influenced by the market and technology, explains the origin of innovations well, while the process indicated by the arrows, describes the linear sections following each other in the innovation process. It is these elements referred to in the section about linear models, and also element models previously. When one considers that this model was constructed in 1974, it can be said to be well ahead of its time.

Some of the advantages of the Twiss model include
- Clear identification of many of the key aspects of innovation
- Illustrating the influence the fostering environment has on the innovation process
- Identifying individuals in the innovation process

Some of the disadvantages of the Twiss model include
- The linearity of the model does not accurately represent the innovation process
- Innovation does not necessarily start with creativity as implied
- Many of the multiple facets of innovation such as strategic/market/technological dynamics are disregarded
- The model is proposed to be generic jet contains many specific innovation tasks destroying the uniformity.

Generic models may find their best application as holistic representation of the innovation discipline. They may be used as foundations for auditing, developing new innovation strategies, educating individuals about innovation, as well as further development of more applied or specific models. Generic models may therefore serve their purpose as holistic examples, but should always reflect changes in the underlying discipline which they represent.

3.2.4.3 Conclusion to Generic and Specific Innovation Models

To enhance the use of generic innovation models, they are often proposed as flexible enough to be adapted into specific models. In this regard the model in question would offer a generic overview and a focused view after specialisation, representing the best of both worlds. This transforming of a generic model should be done with the organisation and modeller present, since the modeller needs to understand all the organisation's structures and procedures. In a way conducting an innovation audit may be seen as gathering information of an organisation, in order to construct a specialised model for the organisation.

The question whether a choice between generic or specific model should be required is therefore debatable. Since the application of the model dictates the type of model required, it should not be an issue.

3.3 Thesis Viewpoint on Different Models

All of the previously mentioned models have positive and negative aspects, concerning clearness of representation, ease of understanding and implementation, as well as modelling perspectives. One might extract from these the most applicable to current requirements, and construct a model based on current literature.

Some of the disadvantages of the models discussed above include difficulty to understand, poor identification of applicable implementation areas, implementation across hierarchical divisions and others. Some of the advantages of the models include good overview, identification of key innovation areas, and illustration of the linkages between different innovation functions.

A factor seldom present in innovation models is representation of individual capabilities. Innovation models often only represent the actions, rather than the source of the actions required. For example: The model by Utterback, as illustrated in Figure 3.11, contains references to problem solving and idea generation, but it refrains from indicating where these capabilities are present in the organisation. If an innovation model is to represent the discipline of innovation, individuals and their skills, emotions and knowledge has to form part of it. After all it is the human factor that makes innovation possible.

It was shown that the type of model is dictated in many cases by the requirements of the organisation. If a model is developed for an organisation, these requirements become of crucial importance. However if modelling is done for scientific clarity or as part of research, the field remains open to the modeller.

3.4 Developing a Proposed Innovation Model

From literature one might construct a representative view of the models already in the public domain. By extracting the most relevant parts from these models, an innovation model for auditing may be constructed.

In keeping with the opening statements in paragraph 3.2, two crucial areas in the technological innovation-modelling arena exist. One being the *innovation process*, the other being the *fostering environment*. To illustrate this, reference is made to models by Twiss in Figure 3.10 and Utterback in Figure 3.11, where the innovation process in a linear form, is supported by an environment consisting of technology, science, society and market factors.

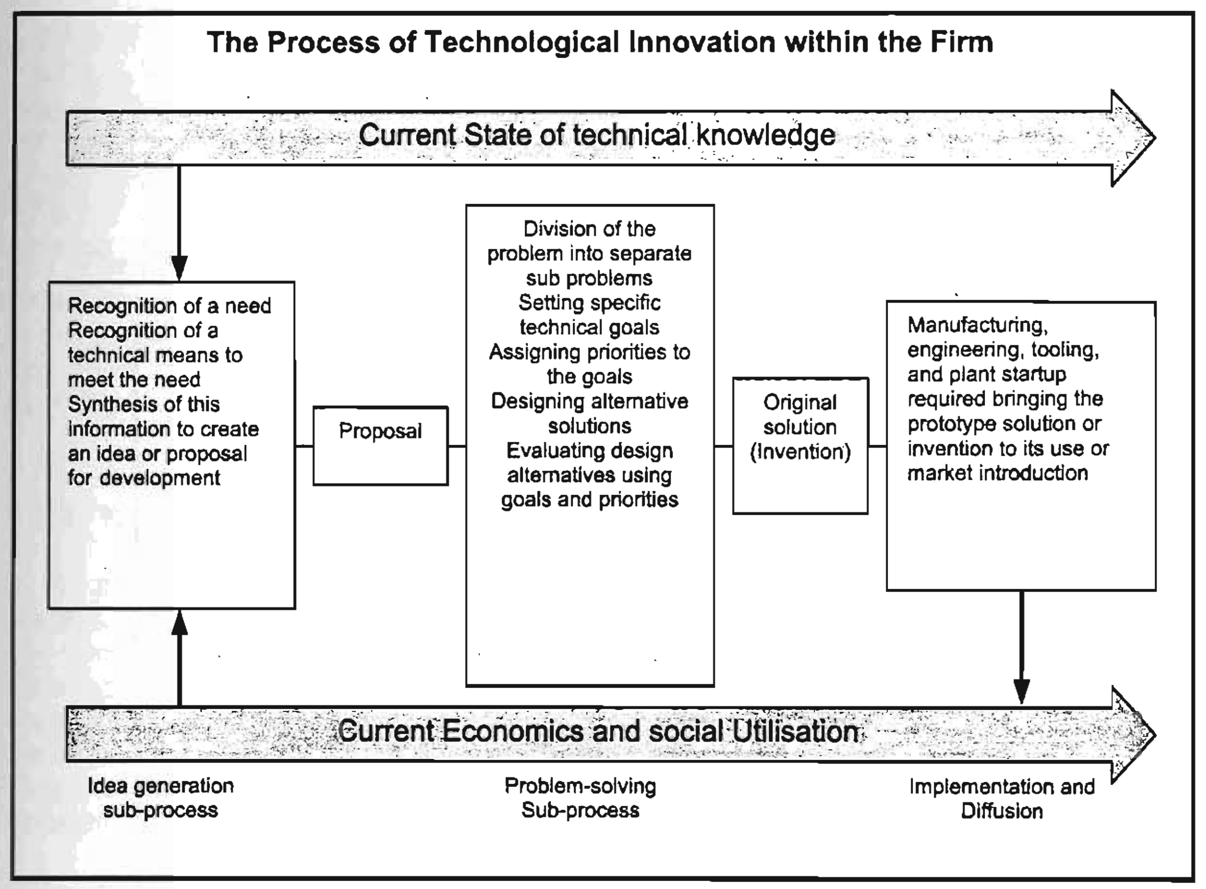


Figure 3.11: The Process of Technological Innovation within the Firm, adapted from Utterback[10]

The duality of innovation may be seen in other models as well, yet it is clearly illustrated in the model by Utterback. The *innovation process* is represented in the centre, beginning with the middle left block, and ending with the middle right block. The two arrows top and bottom represent the *fostering environment.* The innovation process and fostering environment are continuously interacting, as shown in the model. It is clear that with either of the two missing or poorly represented, the total innovation process cannot succeed.

The innovation model developed in the following paragraphs relies heavily on the duality, identified in the model by Utterback. The proposed model might take on a different form from the ones listed above, but on closer inspection most, if not every aspect of the models discussed in the paragraphs above, may be identified in it.

3.5 The Proposed Innovation Model

3.5.1 Model Viewpoint

The aim of the model is to set a clear understandable benchmark for the innovation process inside an organisation, which can be used to focus the innovation audit, and represent its findings. By using a model, many different aspects of a complex process can be represented and used to understand the total process better. By coupling a model of a process with an audit of the process, a powerful tool is constructed for analysis and measurement. The model thus becomes a guide, benchmark and visual representation of the audit findings, and possible recommendations.

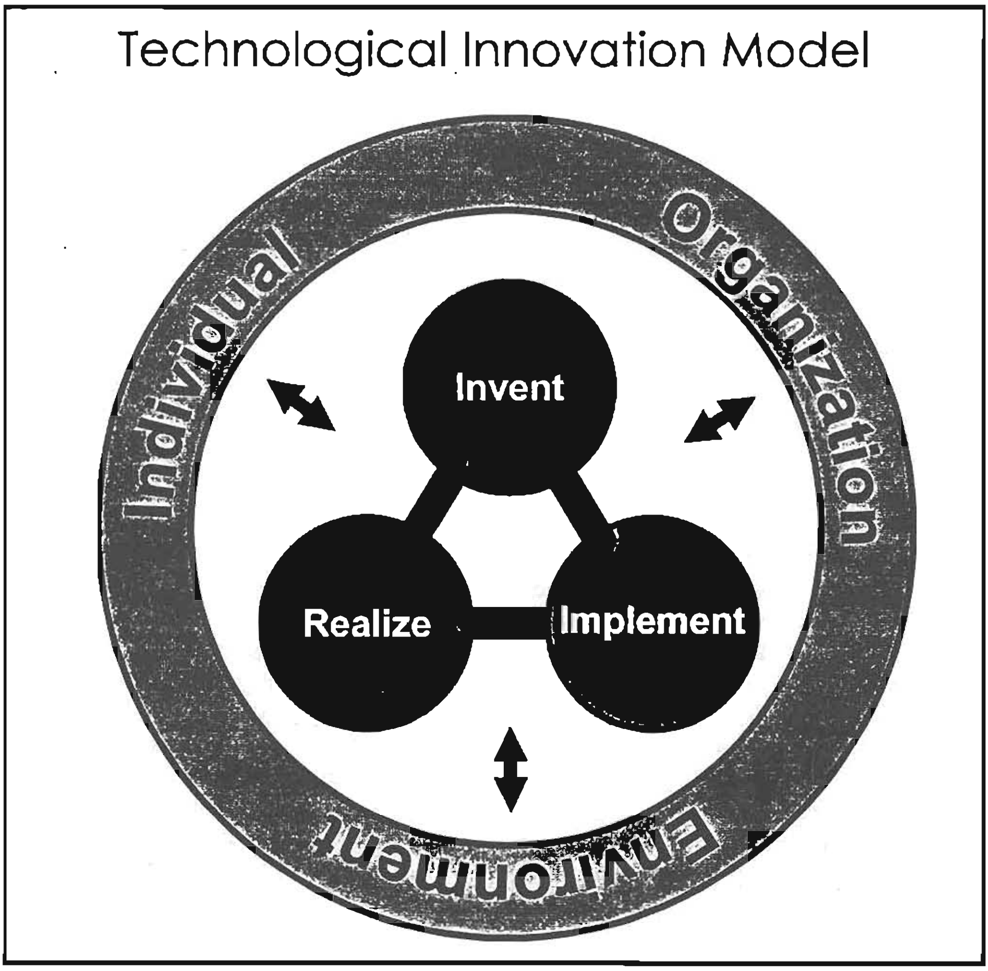


Figure 3.12: The Proposed Innovation Model

As noted previously, several different innovation models exist, and they all have their advantages and disadvantages. The proposed model above embraces these models, and extracts from them many aspects to its own advantage. Concepts such as linear vs. non-linear, implementation depth and generic vs. specific aspects, were carefully considered in the process of building the model.

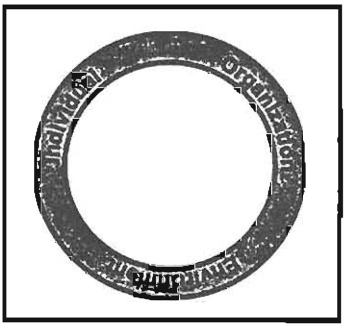
To illustrate the proposed model better, it may be split into two distinct parts. Firstly the innovation *life cycle* or *process*, and secondly the *fostering environment*.

The *life cycle/process* part of the model may primarily be thought of as a linear process, where invention is followed by realisation, which is followed by implementation. The pharmaceutical industry is known for its ability to follow this 'recipe' of new product development quite well.

The *fostering environment* part of the model, is where experience and competencies seated in the organisation are represented. It is often difficult to illustrate how the 'soft' aspects of individuals employed by the organisation influence the innovation process, or where they fit into the framework of innovation. The fostering environment part of the model captures the 'fuzzy/soft' parts of innovation, and integrates them into a sensible, understandable model of innovation.

The following paragraphs will list many of the aspects applicable to *the innovation life cycle/process*, as well as the *fostering environment*. Since the fostering environment is the primary focus in the development of a competence audit for technological innovation, it will be introduced in this chapter and expanded on in a later one. The *innovation life cycle/process* is discussed in some detail.

3.5.2 The Innovation Fostering Environment



In the model the ring, enclosing the innovation life cycle process, represents the fostering environment. The three key terms inside the ring, each represents a part of the fostering environment. The terms **individual**, **organisational**, and **environmental** are representative terms to describe the fields of the fostering environment. They are representative but not absolute, since overlapping between the various fields often occurs.

Why is the fostering environment important?
How does the fostering environment influence the innovation process?
Where does the fostering environment fit in?
What does the fostering environment contain?

These and others are all issues that have to be addressed to understand the importance of the fostering environment.

The fostering environment is important because it influences every aspect of the innovation process. Invention, realisation and implementation rely heavily on the capabilities, leadership and resources seated in the fostering environment. An exceptional fostering environment may often go a long way in improving a poor innovation process. Kanter[23] uses the example of an United States firm, that actually has to lock its office doors over weekends, to deny employees entrance into the building, and consequently their work. The company is able to create such interesting assignments, and such an excellent working environment, that its employees refuse to leave. Just imagine what it would be like to work in such an exiting environment, capable of motivating employees so well!

Organisations consist of employees, and employees are human beings. This fact is often overlooked when innovation models and methodologies are developed. Unfortunately, innovation is primarily a process initiated and completed by humans. Innovation relies on human creativity, drive, leadership and problem solving abilities. The innovation process can therefore only improve if these 'abilities' of the humans are improved. The fostering environment has as primary goal the construction and supporting of an environment that would be able to improve these and other abilities.

Many papers on culture and social aspects of the organisation have been written. Few of these have the innovation process in mind when defining the extent and ramifications of their findings. Unifying these studies with others in the field of innovation may improve the way organisations perceive the fostering environment. Yet before the findings of such studies are accepted, the place of the fostering environment in the organisation will be difficult to define. Ideally an innovation manager might look at improving the fostering environment, or alternatively it might fall under the auspices of human resources or general management. However until a consistent effort has been made to implement a plan for improving the fostering environment, little if any improvements may be forthcoming.

To illustrate some of the aspects of the fostering environment, the three terms defined in the innovation model are discussed below.

3.5.2.1 Individual

Humans are important! Even though every innovation, idea, insubordination or huge success originates with human beings, innovation models seem to discount them as unimportant. Innovation models may imply the importance of the individual, yet it is necessary to indicate where individual, group or organisational competencies are needed in the process of innovation. Finding and assigning the best individuals with the correct competencies to the correct tasks in the innovation process, may often be as important as the task itself.

Innovative companies all state the importance of freedom, creativity and non-conformity, yet all of these aspects are uniquely human. One of the crucial departments in an organisation trying to be innovative, should be its human resources and employment agency. For instance how can managers rely on, and trust employees, if the typical people hired by the employment department are ones with no self-motivation or drive. By hiring employees 'that fit in', the organisation may often create a homogeneous mixture of competencies, with little or no ability to be different.[24]

Entrepreneurs and intrapreneurs are some of the most valuable individuals in the organisation. These individuals have the ability to motivate themselves, as well as the vision and drive to reach their own idealistic goals. Other individuals such as 'sponsors', 'leaders', 'gatekeepers' and 'weirdoes' may play key roles in the innovation process. These individuals often form the backbone of the fostering environment, giving advice and training to novice employees.

> A *sponsor*[25] may for instance provide authority and resources to a blue-sky idea, without the explicit knowledge of the board. Enabling the new start-up to progress to a stage where viability may be proven.
>
> *Leaders* and *entrepreneurs*[26] are able to gather individuals into groups, and excite them about a new project; afterwards following through on the development of a new innovation idea.
>
> *Gatekeepers* are sources of information and may be consulted on a regular basis for advice and information.

While *weirdoes* are the ones stirring the pot of innovation, making sure nobody stagnates in his or her own thought-process.[24]

The method for dealing with change and new technologies, are often influenced by the culture and perceptions of the people in the organisation. If a culture of secure and lethargic job positions have established itself, change will become incredibly difficult. However when employees feel challenged, entrepreneurial and act individualistic, change is less disruptive and is often seen as a new opportunity. Thus through a strategy of continuos change, organisations may keep fit, mentally and capability-wise. This section will be discussed in more detail as part of the innovation audit in chapter and five the audit questionnaire in the addendum.

3.5.2.2 Organisation

The successful application of innovation does not only rely on diverse, creative or brilliant employees, but requires leadership, structure and goals as well. The organisation may assume the role of 'mother' and 'guardian' for new innovations, and therefore act accordingly [See addendum appendix A, Burgelman].

To define a clearer picture of the organisation's tasks, the following elements may be identified:

- *Formal environment setting* — creating an environment where innovation might be born, developed and finalised.
- *Structure* — inventors, scientists, and sales people are not known for their adherence to project management, and a certain measure of structure will enable these employees to reach their goals faster and with less turbulence.
- *Vision* — the leader of innovation is traditionally the one with the VISION, and as such the organisation supports this leader, thereby enabling the continuation of the innovation projects.
- *Mission* — a holistic mission should be defined by the organisation, assigning a place to the innovation inside the diverse aggregate of projects pursued by the organisation.
- *Resources* — a crucial task of fostering an innovation is utilising the correct resources. Even though resources do not make an innovation, the timely access to required ones, does improve innovation speed.

Idealistically an organisation may be defined as a group of individuals, working together to reach a common goal to the advantage of all. In such an environment, the above mentioned aspect would often be easily accomplished, to the advantage of the innovation process. This is seldom the case, for organisations often have pre-conceived structures and methods of operation, with bureaucracy being the innovation exterminator. This section will be discussed in more detail as part of the innovation audit in chapter five and the audit questionnaire in the addendum.

3.5.2.3 Environment

The environment is characterised by the interaction between the organisation and everything outside the organisation. Areas such as technology, religion, politics, social norms, world occurrences, the market, and many other factors have a role to play in the operations of organisations. Of these, the ones that may have a pivotal influence on the organisation may be grouped into *technology, market, industry and P.E.S.* (politic, economic, and social).

Technology has enabled the human race to improve their living and working standards enormously. Without breakthroughs in medicine, agriculture, internal combustion, electronics and social sciences the world would probably still be in the middle ages.

As technology changes, so does the *market* in its needs, beliefs and desires. One may only glance towards one of the building blocks of the American World Wide Web environment, only to find that an incredibly large percentage was built on pornographic web sites. Clearly the market need existed, yet who would have expected the explosion of odorous material that would ooze from this concoction. Evidently the market changed from relatively innocent girlie magazines to hard core sexual intimacy.

The *industry* norms and standards dictate competition and competitiveness. To be able to compete in national and international market, organisations often try to comply or surpass the industry standards. Obtaining adequate knowledge of competitors is crucial, as well as benchmarking one's own operations against the best in the industry.

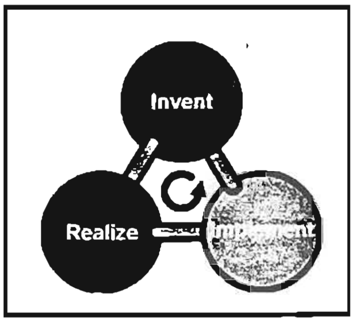
P.E.S. (politics, economics and social) may influence the organisation in various ways. Economical, political and social crises have different influences on the organisation, yet when they occur simultaneously, as they often do, unfortunate things happen. Poor social control, natural disasters or political upheavals often precede economic disaster. Even if these do not directly influence the organisation, the economic realities soon will. Few organisations are able to weather high interest rates, or reduced sales for extended periods of time. The P.E.S. factors are important and should not be disregarded.

Networking is part of the process of interaction with the external environment. Knowing the right people in the right places is often a key ingredient to finding the best opportunities, as well as hearing about the threats beforehand. Individuals with the good contacts outside the organisation, may often be valuable, for they are often able to find exciting opportunities through these contacts

The three areas highlighted in the fostering environment are to a certain extent present in every organisation, regardless of its innovative capacity. Just as every person has some creativity and can learn to improve this[27], so do organisations posess the possibility to learn and become better at innovation. By improving the fostering environment, organisations will improve in their innovation efforts, and might find other aspects of the business, such as customer relations, also improving.

The fostering environment is highlighted extensively in the innovation audit questionnaire, and accompanying documentation included in chapter five and the addendum. The other side of the coin in the *innovation process* contains the recipe-like, innovation life cycle development tasks. *Invention*, *realisation*, and *implementation* are common tasks performed in organisations with strong new product development divisions. These organisations include the likes of 3M, DuPont, Intel, as well as pharmaceutical giants such as Merck & Co., Pfizer, Inc., Schering-Plough and others. The following paragraphs will highlight these three new product development sections.

3.5.3 The Innovation Process Life cycle



In the proposed model, three equally important spheres represent the linear new product development innovation process. The process starts with **invention** then progresses to **realisation,** and ends with the **implementation** phase.
Although the spheres overlap in practise, it is sensible to split them in the proposed manner. This notion is supported by literature as illustrated by these two examples in a non-exhaustive list.

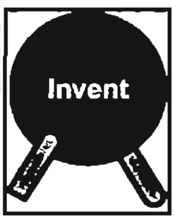
> *'The innovation process has three major components. The first is invention — getting ideas, The second is development — turning ideas into reality. ... The third stage is getting the product on the market and making it a huge success'.*
>
> — Wiersema [28]

> Model concepts:
>
> *'Idea generation sub-process, problem solving sub-process and implementation and diffusion'*
>
> — Utterback[10]

In the model the spheres each represents a part of the innovation process, yet they do not actually represent the true-life situation. A more accurate picture should include overlap and synergies between these units, fusing them together into a continuous process.

Each of the spheres is composed of several key aspects, regarding their main area of focus. It is interesting to note that these aspects might change when different organisations are modelled, and thus the model leans itself toward customisation and better implementation. Some examples of customising the model are proposed at the end of this chapter.

To illustrate the inner workings of the model, the three fields will be discussed below. *Invention* may often be the first process in an innovation, followed by *realisation* and then market *implementation.* However when a product improvement innovation occurs, the implementation phase or market may be the initiator, followed by invention, realisation and implementation.



3.5.3.1 Invention

The process of invention is one of the most fascinating parts of the innovation process. It is here where creativity, luck and 'guts' play a major role in the daily task of people such as researchers, developers and inventors. People have gone as far as saying invention is a non-rational process.[29]

The invention process may often seem to be discontinuous and chaotic, and then at another time linear or even predictable. From a distant perspective invention may seem chaotic and highly unpredictable, yet many factors are responsible for good invention practise. By focussing on these aspects the chaotic areas of invention may be isolated. And after these chaotic areas have been identified, projects may be managed with less associated risk. However, brilliant ideas will never occur on demand, and one should not base planning on the assumption that an idea will be forthcoming.

In this regard, one might then propose that invention is not just about ideas. Such a belief would deliver nothing but crazy, unreachable plans. Invention is about getting ideas and developing them to a demonstrable format for further development.[30] As such, an invention should be proven to minimise risk and reduce setbacks or redevelopment time.[1] Some key elements in this part of innovation include:

- *Signal processing* (contact with external and internal environment)
  To form creative and sensible ideas, the right people, atmosphere and way of looking and thinking about things, are crucial. Without knowledge and some experience, ideas would be frivolous and highly unreachable. Therefore the right technological and market interaction is essential to good idea generation for new innovations. Not only does good contact with the environment stimulate ideas, they are also more in line with what the customer wants at the end of the day. Consider the following example:

  > *One firm spent a good deal of money to develop a special welding torch, for use in repairing automobiles. Not one was sold. Puzzled, the management representatives visited potential customers to find out why. Only then did they learn the torch could not be used on the auto body with the upholstery already in place. The torch would have been a fire hazard. Obviously, the management could have avoided this failure, had it checked with potential customers, before developing such a product.*[31]

  By purposeful analysis of technological trends and market needs, organisations can improve their alignment with reality, and ensure more competitive products in the long run.

- *Ideas workshop* (need recognition and idea generation)
  Ideas always happen. It is how we utilise or promote these ideas that really matter. In the corporate world as many as 80%[32] of all pursued ideas are failures, yet if the process is managed, it is possible to reduce this number. Organisations such as Cisco, Sybase, Hewlett Packard, 3M, Kodak, GE, DuPont, and others clearly indicate their willingness to innovate, by allocating millions of dollars to developing methods and incentives for better innovation.[33] Idea generation forms the starting point of any innovation, and therefore by managing this point, endless futile hours of work and spending of resources, can be tempered.

- *Solutions* (finding solutions for ideas via internal and external channels)
  Finding solutions to problems is where everyday creativity and open mindedness enters. Employees with an aptitude for problem solving especially in creative ways should be cherished by the organisation. Problems are often sources of ideas and by turning problems into solutions into advantages is the prerogative of the highly innovative organisation.

- *Development* (assuring viability of idea and possible continuance of project)

The importance of formal development and verification of ideas and new technologies cannot be overstated. Hewlett Packard uses a system whereby new technologies, which have been proven, enter a system of 'Pizza Bins' where they are stored for inclusion into new products.[34] However to be admitted to this pre-product inclusion storage bins, technologies first have to prove their stability and implementability. A massive amount of research and development is a requirement for any of these new technologies to reach this stage.

Science and research based organisations may often be classified as inventive. These organisations specialise in research and development and seldom produce tangible products for the consumer market. They focus on intellectual products such as test results, new methods, ideas and technologies. These often take the form of patents and publications. These organisations often require external funding, yet provide a valuable source of new information to the world.

Links

Strong ties in this area of innovation should exist between the organisation and the external environment, especially technology and market needs. The invention arena is one of the most fragile parts of the innovation process, and therefore requires the right organisational and social environment.

3.5.3.2 Realisation

Bringing together training, skills, experience and technology, the entrepreneur or organisation has the ability to transform the inventor's idea and change it into reality. This stage has realisation as goal, and nothing else. Although engineers, entrepreneurs and leaders play a large role on this area, all functional people need to be present to influence the development of the idea. Concurrent engineering is the 'buzz'-word used in this phase. In keeping with this, team structures become highly important as methods for bringing together the right people at the right time.

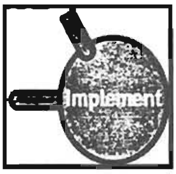
Systems' engineering is the clear and logical choice in detailing the realisation of innovation. Per sé an innovation does not need to be all new. In complex systems, only parts of the total could be new inventions, while many standard components stay in use. System engineering enables the engineer to construct a solution to an identified need, by fusing inventions and current technologies into a single product. The common term used for this is technological fusion, and a good example is the integration of current cellular telephony, Internet connection, or even personal computers, Internet connectivity and television entertainment. Although some new inventions do play a part in these new products, much of the old stays in place, therefore requiring complex systems integration of old and new.

A detail discussion of systems engineering falls outside the scope of this thesis. However some facets of the discipline is discussed in the addendum [Appendix B] to illustrate the process of realising an innovation.

This concludes the section on realisation, and the importance of the section may be observed in its detailed discussion in the addendum [Appendix B]. When innovation is discussed, the hard work and hours of intense design and development are often poorly planned. Taking an idea and transforming it into a product with exciting attributes at a producible cost, is difficult in the extreme. Without a highly competent realisation team, organisations will never see their blue-sky ideas realised in practise.

Some of the disciplines involved with the realisation process, might include engineers and project managers. Interaction between the engineers, project managers and other role players such as customers, suppliers, and manufacturers are crucial, and should not be neglected in this phase.

Links
The realisation of the innovation ties strongly with organisational structures and routines, on how to design, develop and produce a new product. Individual involvement is crucial, as a great number of goals and deadlines need to be met within budget and on time. Interaction with the market and technology is strong, but in a supply of information and technological know-how, rather than new trends or needs.



3.5.3.3 Implementation

Manufacturing and marketing are unlikely bed partners, but this phase of the technological innovation modelling process focuses on producing, introducing and selling new innovations.

In recent times developments in automated manufacturing and outsourcing of non-core processes, created the ability for organisations to split the production side of the product away from the innovation process. Production has become such a specialised field, that it often serves the organisation better to outsource the high volume production of a product, than to try and do it themselves. This has the advantage of reducing organisational diversity, as well as the upkeep of huge manufacturing plants with large overheads. Processes such as laser cutting specialised machining and die pressing may all be safely and profitably outsourced. This affords organisations low overheads and no worries about keeping up with new manufacturing technologies.

Marketing forms an integral part of innovation. It is here that the product needs to be implemented and shown to work. Marketing has long since passed the era of selling appliances from door-to-door. Current day marketing is a high-powered monitoring and knowledge-based industry, with sophisticated advertising of products over a range of media types. Even with all today's tools and toys, the marketer, with the right product at the right place and time, often has the advantage and will have the best results.

Diffusion of innovation into the identified market share, can be a very expensive, as well as frustrating task. Barriers to entry and consumer apathy have to be overcome, in developing and teaching new users. In the quest for knowledgeable users Von Hippel researched and identified many characteristics of lead users.[35] These users are often technical with the persistent need to improve their current tools. By looking at the changes these people make to their current apparatus, ideas for new developments may be found. Lead users are often used for beta testing new products to determine the possible success value of the product.

Marketing and strategies aimed at specific segments, are some of the keys to the diffusion of new innovations. A totally new concept might still take years to become an accepted method or product. A good example in this case is the APS device developed by Tech-pulse South Africa.[36] Gervan Lubbe, the patent holder and director of the business, spent five years testing, marketing and persuading potential customers to use the device, before it became accepted.

> The APS (Axio Potential System) device induces electromagnetic pulses between two electrodes, and if placed on a human body or muscle, will induce electromagnetic waves. This results in the human body producing natural pain killing endorphins, which naturally reduce the pain. These endorphins are the body's natural painkillers, and are therefore much safer than painkillers.

The point in case being it took the inventor of this system five long years to educate the market enough to be able to sell the product. Since the market is also included in the external environment, it will be discussed further in the audit questionnaire.

Some of the most common participants in the implementation part of the innovation cycle are market research organisations and advertising agencies. Other businesses such as distributors, marketers, supermarket chains and other general retail stores are all part of the implementation of innovation.

Links
The production side in this section has strong efficiency and new methods linkages with the technological environment, but almost no market related interface, where as the marketing side concentrates on the moods and demands of the market, and needs to be highly in tune with future customers. This section does not require as much organisational structure or backing as the other innovation areas, yet it is responsible for interaction with them, to ensure the market needs are realised and addressed.

3.5.4 How the Model Works

From the previous section it should be clear what each of the concepts in the proposed innovation model represents, and where they fit into the innovation process. It is important to understand that the model can be implemented on several levels in the organisation, be it strategic, management or disciplinary. Thus to use the model effectively, it should be accompanied by an innovation audit, measuring specific aspects of the innovation process in the organisation. These measurements may then be represented as bar charts in referent to the elements in the innovation model. To illustrate how the model could work, the following scenarios are proposed:

> **Strategic**:
> The South Africa organisation the CSIR (Council for Scientific and Industrial Research) was a basic research institution, supported by the government for a long period of time. Since 1994 several changes in South Africa have resulted in their funding being drastically reduced. This forced the CSIR to look at other sources of income, and specifically at improving the marketing of their services as well as some of their current products. On an industry level the CSIR could be regarded as an **inventive** organisation, trying to improve its **realisation** and **implementation** areas. It could be said that the CSIR should try to improve the realisation and implementation aspects of its business, but this is not necessarily the best option. If for instance other organisations in the same industry as the CSIR found its best markets to be for inventions, the CSIR would be at fault when improving its realisation and implementation areas. They could rather improve their inventive capabilities and serve the best market, which might be the USA Basic Research Council.

What it boils down to, is that innovation is not a clear-cut process with neat inputs and outputs. Often the innovation model only serves as a basic foundation for a much more detailed innovation process. Therefore, finding the specific blend between invention, realisation and implementation for each organisation to best serve its market and utilise its resources, may be done with the model as foundation and its possible extensions, as proposed in paragraph 3.6, as directions.

Management level:
The organisational level representing this area the best is the project management level. In this environment projects are continually started, developed and implemented and the model finds its best application here. The 'aggregate project plan', as discussed by Wheelwright[1] plays a role in deciding the type of projects chosen, and how they fit into the innovation model. For instance an organisation might face a choice between improving its production process through a new innovation, or developing a new service enhancing its current products, or developing a totally new product. Each of these projects has a different map on the innovation model, and the organisation should choose the best fit. This ensures that the organisation has the best chance of being successful in the new project. This method of fitting projects to the company's capabilities, ties in with new technology and core competencies, where new technologies are bought to fit the needs of the organisational strategy and future development focus.

Disciplinary level:
Individual employees can easily feel like cogs in a wheel of a big turning machine. To improve efficiency and innovativeness in employees, the innovation model may be used. Each employee has his or her own way of thinking and doing things, but by encouraging them to adopt the innovation model, their lesser developed skills may be improved. In problem solving for instance, the three areas *invent*, *realise* and *implement* play key roles in certain stages of the solution. By consciously ensuring aspects in the innovation model are met, a better chance exists for improved solutions. By focusing on the environment of the employee, the model helps in improving innovation climates and cultures.

It should be understood that the specific aspects and elements of the model would change considerably when implemented on the different levels within the organisation. For instance: when the strategic level is modelled, the external environment on the model would change significantly, and so would other aspects specifically connected with the industry environment. This would differ from the innovation development level, where the term **organisation** in the model would either change or possibly fall away. In the individual level the model would change to exclude individual, since it is this that is being modelled.

Until now the focus in developing an innovation model has been one of setting a standard for the innovation auditing process. However, different innovation strategies are necessary in different industries, and developing the innovation model into an organisational specific one, would prove useful. The following paragraphs will show some examples how the model might be customised to the organisation's needs. These examples proposed here are pure speculation, for it is the organisation itself and not the modeller that should define the specific elements in these models.

3.6 Proposed Implementations for the Proposed Innovation Model

The innovation model will ultimately prove its validity and importance in the application of the model. To illustrate the possible expansion and customisation underlying the model, two examples will be illustrated.

Innovation models often attempt to capture some degree of structure, as well as contents of the innovation process. The model developed in this thesis does not contain any content of the innovation process. Rather it contains the 'headings' of the contents of the innovation process, and may therefore be expanded showing the underlying body of innovation. Considering the model to be a master for a much deeper development of information enables the innovation model to be customised to a specific organisation, or even one innovation project alone. The model may be extended as shown in Figure 3.13.

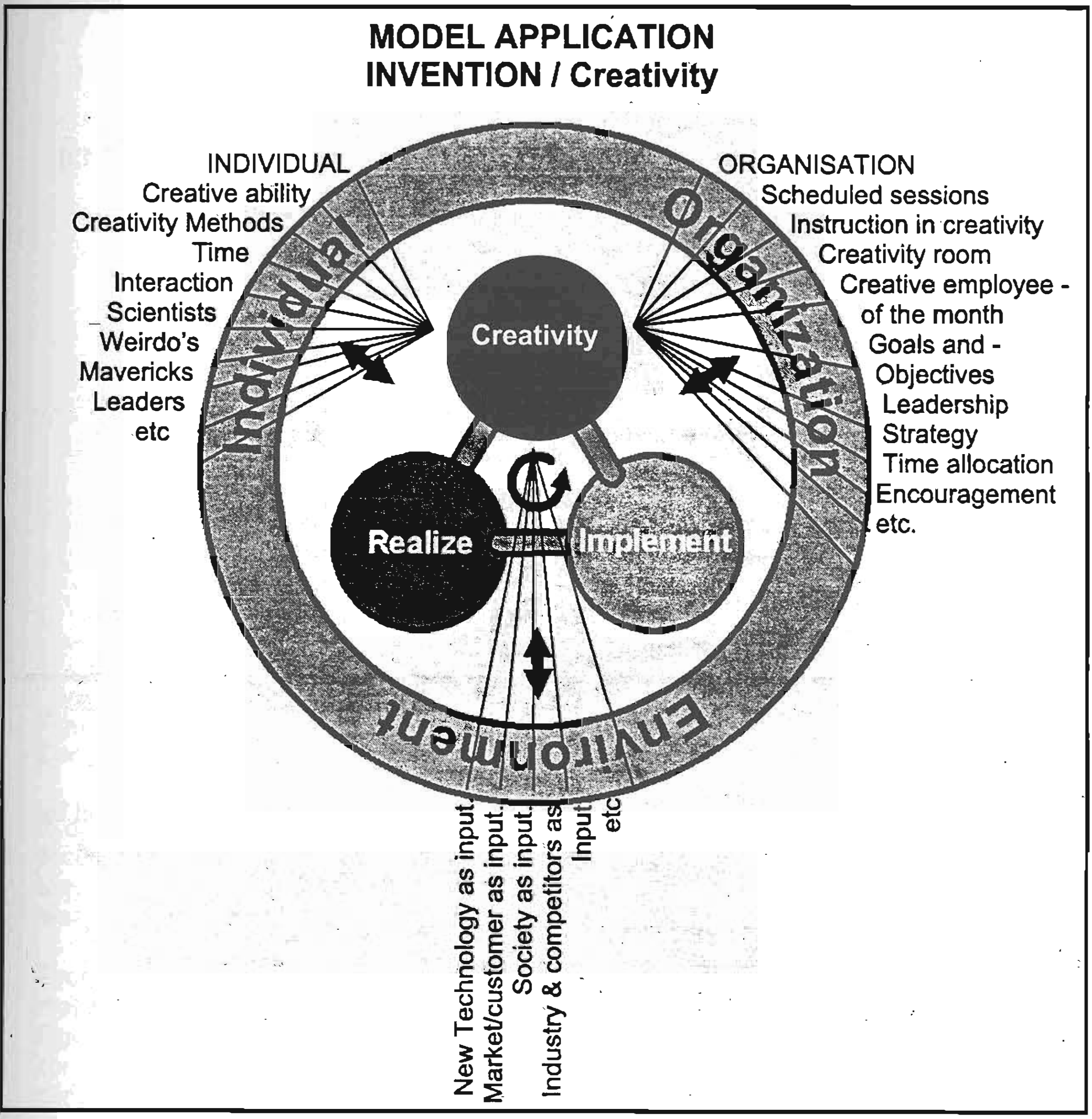


Figure 3.13: Innovation Model showing Sub-Section Invention, and Focussing on Creativity

Each of the three main innovation functions, *invent, realise,* and *implement* may be split into subsections, containing the more specific steps of innovation. For each of these sub-sections, the model may then be developed to suit that particular field. Figure 3.13 illustrates a single subsection of the invention function. The creativity sub-section requires specific individual, organisational and environmental characteristics to function optimally as part of the innovation process.

This subdivision of the model makes it complex, but far more flexible than many current innovation models. There might be some difficulty in assigning values and meaning to every proposed sub-section, but the goal is not to iron cast a model of the innovation process inside the organisation, but rather to stimulate thought and a holistic understanding of the innovation process.

Other sub-sections that may possibly be used in the model may include the following: (This is not an exhaustive list)

Invention

- Interaction — Contact with technology / market
- Creativity — Creative idea generation / need recognition [Figure 3.13]
- Research — Find solutions to ideas
- Test & model — Develop solutions to demonstrable format
- Licence — License out or develop further

Realisation

- Initialise — Program initialisation
- Approval — Filter, prioritise, choose
- Resource — Assign resources
- Plan — Plan and specify
- Acquire — Technology acquisition
- Design — Design and develop to maturity [Figure 3.14]
- Test — Test the systems
- Pre-production — Production concerns

Implementation

- Produce — Full-scale production
- Develop — Market development / customer development
- Commercialise — Innovation commercialisation / diffusion
- Support — After sales support

Example 2, as seen in Figure 3.14, illustrates a possible application of the model in the realisation sub-section, with the focus falling on design:

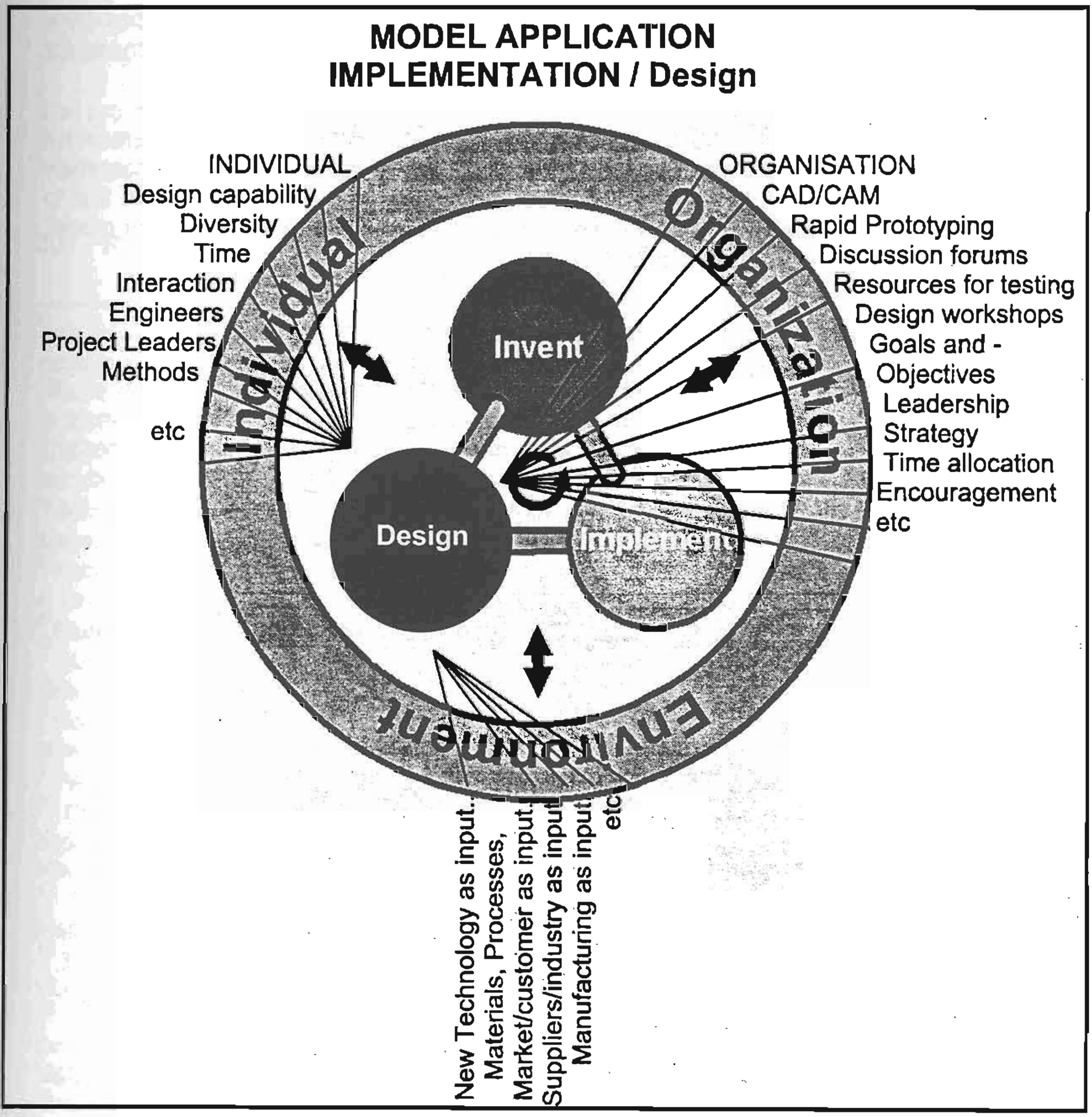


Figure 3.14: Innovation Model showing Sub-Section Realisation, and Focusing on Design

In order to model an organisation with this model, each of the above mentioned sub-sections should be classified in terms of individual, organisational and environment terms. The proposed sub-sections each requires unique interaction with the three areas, as can be seen in the two example models provided.

Every innovation process can thus be divided into many sub-sections by following the master model. By integrating the many two-dimensional models as illustrated in Figure 3.13 and Figure 3.14 into a single three-dimensional innovation model, consisting of two-dimensional slices, a comprehensive innovation model may be constructed.

Many links between the different sub-sections of the innovation process exist, and they emerge when comparisons are drawn between the various two-dimensional models. These links may prove to be one of the key areas where organisations differ from each other. Possibly even the place where the essence of their methods for applying innovation lies.

Further development of the model is beyond the scope of this thesis. It remains a field where successful research and application may be done. To successfully develop the model further, some practical trials, where organisations would like to customise the model, would prove useful. The development of a 'best practise model' may serve as a starting point in this regard.

3.7 Pros and Cons of the Proposed Model

The proposed model does not claim to be the best, nor exhaustive in its representation of the innovation process. It does try to offer a holistic impression on a fragmented discipline. The implementation of the model may hold some interesting possibilities, yet is left open for further development. Organisations may find, by using the proposed innovation model, that they might be able to restructure their innovation process more sensibly.

The following advantages and disadvantages are evident:

Disadvantages:

- The model is very generic and difficult to understand at first glance
- There are few elements of innovation in the model
- No mention is made of different types of innovation
- There is too much emphasis on the individual
- The model is too simplistic for a highly complex industry
- The market is neglected
- Manufacturing is neglected

Advantages:

- The model offers an holistic view of the innovation process
- The model identifies key aspects of the innovation environment
- The fostering or 'soft' aspects of innovation is accurately depicted

It is not easy to develop a model for a diverse field, such as innovation. Through consultation with industries, the model developed above has been validated. Not one of the industries consulted reported any problems, disagreements, or invalid aspects of the model. Although this does not guarantee the validity of the model, it does enhance its stature.

3.8 Conclusion

This chapter reached a conclusion in the development of a generic innovation model with the advantage of being scalable for specific applications. It was observed that many aspects influence the development of an innovation model, but the area of implementation ultimately dictated the best possible model to use. Therefore since the model in this chapter was developed to serve as a foundation for a competence audit for technological innovation, it included a holistic overview of the *innovation process* as well as the *fostering environment*.

In the following chapters the proposed innovation audit will make extensive use of the proposed innovation model. However, it will not implement the further developments proposed in customising the innovation model as discussed in paragraph 3.6. Each of the proposed audit sections will be based on the three areas identified in the fostering environment.

The proposed innovation model was developed to serve as structure and foundation for the innovation audit. The following chapters will show the development of an audit methodology and also how it conforms to the proposed innovation model.

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