

SYSTEMS ENGINEERING AND CONCURRENT ENGINEERING: WHAT'S IN IT FOR MANUFACTURERS OF MATURE INDUSTRIAL PRODUCTS?

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ABSTRACT

Studies on both systems engineering and concurrent engineering tend to be set in the context of high-technology industries: typically weapon systems and aerospace for the former and the automobile industry for the latter. In South Africa, for historical reasons, a large segment of manufacturing industry comprises mature, relatively low-technology heavy mechanical and electrical engineering companies manufacturing industrial products. This paper examines the common ground between systems engineering, concurrent engineering, and the challenges of managing and rejuvenating mature businesses. A combined product development process, tailored to meet the needs of manufacturers of mature industrial products, is presented.

OPSOMMING

Studies in beide stelsel ingenieurswese en gelyktydige ingenieurswese is normaalweg onderneem in hoë-tegnologie nywerhede: tipies wapenstelsel- en ruimtevaart nywerhede in die eersgenoemde en die motornywerheid in die laasgenoemde geval. Weens historiese redes kan 'n groot komponent van die Suid-Afrikaanse vervaardigingsnywerheid beskryf word as volwasse swaar meganiese en elektriese bedrywe van relatief lae-tegnologiese aard. In hierdie studie word die gemeenskaplike grond tussen stelsel ingenieurswese, gelyktydige ingenieurswese en die uitdagings verbonde aan die hernuwing van volwasse ondernemings ondersoek. 'n Proses vir die ontwikkeling van produkte, saamgestel uit die twee ingenieursbenaderings en aangepas om te voldoen aan die behoeftes van volwasse nywerhede, word voorgestel.

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1. INTRODUCTION

There are two dominant methodologies for new product development in current use worldwide: Systems Engineering (SE) and Concurrent Engineering (CE).

SE has its roots in the electronics, military and aerospace industries and it provides a systematic approach to the design and development of complex engineering systems [1]. It is still practised mainly in this domain. CE grew out of the American automobile industry's efforts to emulate the Japanese approach to product development. It tends to be applied more at the product and subsystem level and has a strong emphasis on reduced development cycle time as a source of competitive advantage.

Studies on both methodologies tend to be set in the context of high-technology industries, for example; weapons systems, aerospace, computers, consumer electronics and automobiles.

Where do these methodologies apply in the South African context? Industrial activity has historically been concentrated in two main areas: the strategic quasi-government organisations (such as SASOL, the Atomic Energy Corporation, Eskom and Armscor) and the manufacture of capital equipment for the mining industry (typically electric motors, transformers, pumps, mills, crushers etc.). The latter were, and often still are, manufactured under license to European companies [2].

The armaments industry became particularly strong in the field of engineering product development because the technology could not be licensed and substantial government funding was available to meet strategic defence objectives. SE was used extensively in these development projects.

The "New South Africa" has a very different set of priorities. Gold has lost its glitter and the defence budget has been cut back drastically. The nation now looks to the manufacturing sector to provide employment through growth in exports.

In this context, product development in the manufacture of mature industrial products is an important issue. These "Cinderella" industries do not have the glamour of high-technology industries nor the marketing opportunities of consumer industries, but they are a vital base function in the economy. Competition is mainly price based, resources are limited, and when allocated to development must be used sparingly but with maximum effect.

In this paper three subjects are researched through literature reviews: concurrent engineering, systems engineering and the management and rejuvenation of mature businesses. A development process is synthesised by combining and tailoring CE and SE to suit the requirements of manufacturers of mature industrial products

2. CONCURRENT ENGINEERING

Definition and Background. According to Gardiner [3], concurrent engineering has only been in existence as a recognisable topic since the mid 1980s. He quotes the original definition from the US Institute for Defence Analysis, Report R-338, 1986: *"Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life-cycle from concept through disposal, including quality, cost, schedule and user requirements."*

CE has two key characteristics; firstly, as the name implies, the various activities run concurrently and secondly, they are carried out by a multidisciplinary project team. A third vital element is a strong focus on total customer satisfaction [4,5].

According to Hartley [4], many Japanese companies have been using the basic elements of CE successfully for over thirty years. They did not call it CE, but the success of Japanese

manufacturing, particularly in the automotive industry, created intense competitive pressure on American and European automobile manufacturers [6].

Quality, productivity and speed were the new competitive imperatives; the Japanese were able to bring a new model to market in about two thirds of the time it took in America or Europe [4]. This situation led to the ever popular pastime of trying to understand and emulate the Japanese way. These efforts have resulted in the new product development methodology known as concurrent engineering.

Goals, Objectives and Benefits. The primary objective of CE is to reduce the development cycle time for new products. CE addresses both quality and efficiency but primarily it addresses speed. Fast track development enables a company to increase cumulative profit from a product and to create a technological lead over its competitors [7].

World-class CE is strongly customer oriented. Products must not only be early to market, they must meet customers' needs and expectations precisely with a high level of quality. This is achieved through the application of quality function deployment by a multidisciplinary team.

Benefits listed by Hartley [4] and Clausing [5] include:

- Reduced time to market.
- Product that precisely matches customers' needs.
- Quality is designed and built into the product.
- Increased product reliability.
- Reduced product cost.
- Reduced manufacturing and field costs.
- Product variety and corporate flexibility.
- Improved cash flow.
- Large and continuous improvements.
- Less risk of product commercial failure.
- Fewer changes late in the program resulting in reduced development costs.
- Reduced number of in-house modifications.
- Reduced production ramp up times.
- Reduced production lead times.
- Optimised vendor performance.

Many of these benefits are as much due to the use of a multidisciplinary project team as to the process and tools of CE. The benefits impact upon virtually every aspect of a manufacturing organisation. It is clear why CE has become an essential technique for any company aspiring to world-class status.

Process Concurrency. Clausing [5] states: "*Product design, production-process engineering, field support development, and all other elements of product success are addressed from the beginning as an integrated set of activities and objectives.*" At the macro level it is these three processes that run concurrently. Within these processes there are sub processes that also run concurrently to some degree.

Process concurrency, as compared with a traditional serial or "Over-the-Wall" development process is like a game of Rugby as compared to a relay race [8]. In Rugby, the whole team goes in to play at the same time in a parallel effort, strategising and harmonising to achieve a common objective.

Full process concurrency is not achievable; "*...in the natural flow of work some things are done before others. Concepts are selected before detailed design, and production tools are designed before they are built, for example*" [5]. The degree of concurrency must be tailored to suit the project and its process interdependencies.

The multidisciplinary team is a crucial enabling factor in process concurrency. The communication between team members ensures that the parallel processes are aligned at all times. This real time sharing of information reduces iterations, rework and development time, also reducing development and product costs while improving quality [4].

The Multidisciplinary Task Force. Hartley [4] says of CE; *“Both the team approach and the use of disciplined techniques are essential; neither will provide the potential gains without the other.”* Integration is the core of CE, achieved largely through the multidisciplinary team.

Pawar, in Syan and Menon (Ed.) [9], recommends a “Project Team Structure”, illustrated in Figure I, for CE projects. (This is Clark and Wheelwright’s [7] autonomous team renamed). The team is normally temporary, being disbanded after the project. Team members work full time on the project, independent from the functional areas from which they were drawn. The team leader is normally a senior manager who outranks the functional managers. Team members are typically drawn from the following departments: design engineering, manufacturing, marketing, purchasing and finance. Representatives of key suppliers of components and manufacturing equipment are often included [4]. On a large project there is a “team of teams” reporting to a top level team lead by the project leader [5].

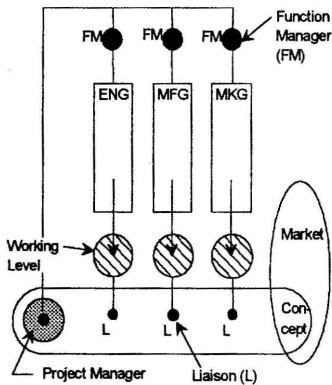


Figure I: The Project Team Structure

better integration of components into the product and higher productivity from capital equipment. The supplier also becomes an extension of the company’s knowledge and resources [4].

Concurrent Engineering Tools. World-class users of CE make use of an extensive array of tools in the product design and development process. The most important of these tools are QFD (Quality Function Deployment), DFMA (Design For Manufacture and Assembly), FMEA (Failure Modes and Effects Analysis) and Taguchi design methods [4,5,9].

QFD is an integrative, customer oriented tool. *“It provides a structured framework to translate ‘the voice of the customer’ into the actions and resource commitments needed to meet customer expectations”* [9]. This framework is based on a chain of matrices that successively translates customer requirements into design requirements, design requirements into engineering design and so forth through parts characteristics, process planning and production planning [9,10].

Customer and Supplier Involvement. CE is strongly customer oriented. Market research aims to capture the customers’ needs and preferences in their own words. Then, having captured “The Voice of the Customer”, quality function deployment is used to convert user requirements into a product specification. In many cases, particularly if the product is industrial, a customer representative will be included in the development team.

In CE, purchasing from multiple suppliers at the lowest price gives way to long term relationships with suppliers and single sourcing of a given item to allow the supplier to achieve economies of scale and faster progress down the learning curve. Often vendors for key items are identified at an early stage and then co-opted onto the development team. This results in

DFMA and FMEA are both used to eliminate poor design features, those affecting manufacture and reliability. Taguchi design methods are aimed at achieving robust design; a design that can be produced with good quality, despite variables in the manufacturing process.

Other commonly used tools include design for maintainability and supportability, product competitive bench marking and the Pugh concept selection matrix [5].

Information systems also play a vital role in speeding up development and facilitating communication within the development team. Modern, integrated CAE/CAD/CAM systems are essential tools. They are combined with knowledge bases and document management systems that make all relevant information instantly accessible to all team members by means of networked computers.

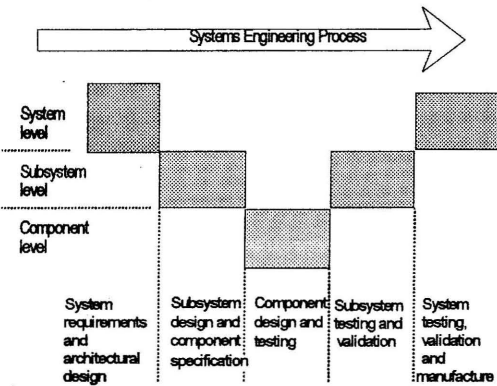


Figure II: Top-Down Bottom-Up System Design

3. SYSTEMS ENGINEERING

Definition and Background. The term “Systems Engineering” was used as early as the 1940s by Bell Telephone Laboratories [1]. SE was developed specifically to cope with the growing complexities of designing and developing large scale telecommunications and military systems during the aftermath of World War II.

De Klerk [12] defines SE as follows: “Systems engineering is a logical and systematic sequence of activities and decisions transforming an operational need into a description of system performance parameters and a preferred system configuration which satisfy the (user’s) requirements.”

SE is characterised by an emphasis on the “whole system” and the “system life-cycle” [1] and a bias towards the design of complex systems.

On the whole system dimension, SE applies a top-down, bottom up approach (see Figure II), establishing cost and performance parameters and a conceptual design at the system level, then working down through the systems hierarchy, allocating requirements to each level in such a manner as to ensure that the final components of the system will combine to meet the cost and effectiveness targets.

Throughout this top-down design, optimisation and specification of the system, the entire system life-cycle is taken into account; manufacturing processes, operating procedures and costs, maintainability, logistic support, phase out and disposal are all considered from the very earliest phases of the design and specification process.

Goals, Objectives and Benefits. The primary objective of SE is to achieve a system level design that, having made an efficient and economical evaluation of all reasonable alternatives,

Stage-Gate Systems. A documented, repeatable and improvable development process is an essential ingredient for success [11].

Cooper [8] advocates a stage-gate system. The documented process is broken down into logical stages with a gate at the end of each stage in which the results of the previous stage are reviewed and go/kill/hold/recycle decisions are made. Action plans and resource allocations for the next stage are also reviewed before a go decision is made. Such a system ensures timely top management involvement and secures their ongoing commitment.

meets the end user's needs in all operating scenarios at the lowest possible overall cost of ownership [1].

This objective is normally defined in terms of cost effectiveness. Cost effectiveness is a trade-off between the life-cycle cost of the system and the system effectiveness. Typical elements of life-cycle cost are: R&D cost, manufacturing and/or construction cost, operation and support cost, and phase-out/disposal cost. System effectiveness is a function of performance, manability, operational availability, supportability and capacity [13].

The primary objective is realised through the achievement of the following secondary objectives:

- A comprehensive definition of the system (user's) requirements.
- Selection and specification of the combination of technologies, subsystems and products that achieves the optimal trade-off between life-cycle cost and conflicting system requirements on many different dimensions.
- Validation of the chosen configuration through test and evaluation. Tertiary objectives can also be identified:
- To minimise the required engineering resource for, and cost of, development.
- To break down the system into manageable components yet keep the overall system perspective.
- To ensure that design problems are identified at the earliest possible stage and corrected before significant costs have been committed.

The benefits of achieving these goals are direct and self explanatory, unlike those of CE which tend to be indirect and sometimes unexpected.

The Systems Engineering Process. The process of SE is an iterative design approach which has both a fine and a coarse structure. The fine structure consists of the iterative application of the following steps [14]:

Problem definition. At system level, user's requirements and constraints. At component level this might be a functional requirement.

Value system design. A value system is required to objectively determine the "goodness" of each alternative solution to the problem.

(System) synthesis. The generation of possible solutions (system concepts) to the problem.

(Systems) analysis. Predict and analyse the performance of the synthesised solutions.

Optimisation (and evaluation). The value system is applied to test the goodness of solutions which are then combined, modified or discarded until an optimum solution is identified.

Decision Making - Select the best solution or return to the system synthesis stage and reiterate.

Planning for action - The next cycle of the design process must be planned.

The coarse structure is linked to the phases of the system life-cycle and represents higher level iterations in the design process hierarchy. The phases are typically demarcated by baselines at which major design reviews and approvals take place [13,15]. These phases and baselines are tabulated in Table 1:

Phase in Life-Cycle	Baseline
User Requirement	Requirement Baseline
Conceptual Design	Functional Baseline
Preliminary Design	Allocated baseline
Detailed Design	Product Baseline
Industrialisation	Manufacturing Baseline
Production	Modification/Upgrading
Operation	Modification/Upgrading

Table I: Design Phases and the Life-Cycle [13,15].

Within this iterative process there is also a top-down, bottom-up progression through the systems hierarchy as depicted in Figure II.

In effect, the phases are “stages” and the baselines are “gates”. Therefore, the notion of stage gate processes is inherent to SE. In fact, SE utilised this concept long before it was popularised by the custodians of CE.

Organising for Systems Engineering. SE, because it tends to deal with large scale development, affects the structure of the entire organisation. SE is also very project management oriented and the structures preferred by Blanchard and Fabrycky [13] are classic project structures; the matrix organisation and the project-staff organisation.

In a matrix structure, staff are organised in functional departments but a project management structure cuts across the functional structure, project managers having project authority over individuals from the functional departments to create a multidisciplinary team for each project.

The project-staff organisation is arranged by project, each under a project manager, but specialist services are provided by focused staff departments.

Systems Engineering Tools. SE has two key front end processes, requirements analysis and functional analysis [13]. Requirements analysis captures the customers’ expectations and establishes the required system performance, the operating environment and any system constraints. Functional analysis builds on the requirements analysis to translate the requirements into a hierarchy of functions that the system must perform to fulfil the user’s need. These two processes are analogous to the first two matrices of the quality function deployment process but tend to be conducted in a rather more formal and mathematical manner. This more rigorous approach extends to the use of decision analysis techniques during systems analysis.

A more rigorous and mathematical approach is also the main difference between SE and CE in the use of design for manufacture, reliability, maintainability and so forth.

As in CE, modern CAE/CAD/CAM systems are used extensively, together with integrated design and information databases. An additional tool in SE is CALS (Computer-aided Acquisition and Logistic Support) [13].

Formal Documented Processes. SE is in itself a formalised process but it must always be tailored to suit a specific project. This tailoring is achieved by generating a “Systems Engineering Management Plan” (SEMP) early in the conceptual design phase.

The SEMP covers the activities and milestones necessary to achieve the SE objectives. Blanchard and Fabrycky [13] identify three major subsections of the SEMP:

Technical program planning. This is the project management element of SE and includes the planned organisational structure, the statement of work, work break down structure, project schedules and the project budget.

SE process. This section documents the process of system realisation including the stages and baselines as shown in Table 1. It is analogous to the stage-gate systems used in CE.

Engineering speciality integration. This section integrates the speciality programs such as reliability, maintainability and integrated logistical support with the main system design process.

4. MANAGEMENT AND REJUVENATION OF MATURE BUSINESSES

In order to explore the applicability of CE and SE to manufacturers of mature industrial products it is necessary to examine the nature of product, business and industry maturity and the associated management challenges.

The Sigmoid Curve. The Sigmoid Curve is the S-shaped curve that describes human life, the rise and fall of empires, the growth of a technology and the life-cycle of a product [16]. Figure III shows how the phases of a typical technology life-cycle correlate with the S-curve. [17,18]. In the context of a product, Twiss [18] identifies four S-curves of relevance.

Technological life-cycle. Representing certain performance parameters relating to technologies that are embodied in the product.

Market S-curve. The growth of the market for the product.

Industry life-cycle. The growth of the industry; normally closely related to the growth of the market.

Product life-cycle. A specific model or fashion has a limited life before it must be replaced with a new model or style. It is more applicable to consumer products than industrial products.

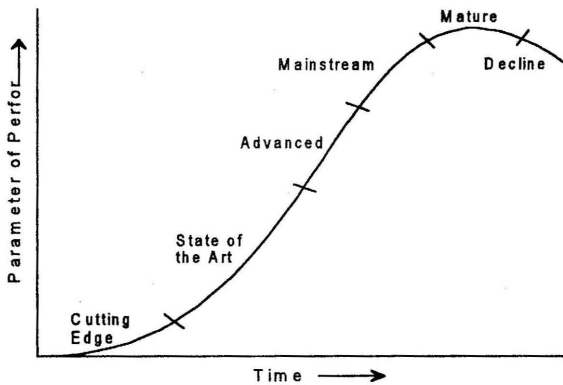


Figure III: The Technology Life-Cycle [17,18]

Popper and Buskirk [17] believe that for industrial products the underlying technology life-cycle is far more relevant to the pattern of sales over time than the product life-cycle. Clearly there is a close correlation between technology life-cycles, the market S-curve and industry life-cycles. In particular, manufacturers of mature industrial products utilise mature technologies, operate in mature markets and can be described as mature industries.

Product, Business and Industry Maturity.

Product Maturity. This is regarded as the stage in the product life-cycle when sales level off and strategies become more defensive, typically aimed at sustaining market share and margins rather than growth. The competitive environment stabilises with a relatively small number of players and is usually oligopolistic in nature. Downward pressure on prices and limited growth in sales gives rise to intensive cost reduction efforts [19].

Business Maturity. Goold [20] identifies several types of mature business. The primary criterion for a mature business is slow, zero or slightly negative growth in the market served by the business. Other criteria include: the competitive significance of technical change, the stability of the customer base and competitive environment, and the maturity of the product. They may be cash rich or competitively weak with poor profitability.

Industry Maturity. In the early stages of an industry life-cycle the high levels of uncertainty for both producers and users results in a wide variety of product configurations and technologies. As product design stabilises, attention is turned from product innovation to process innovation and product features cease to be the prime source of competitive advantage. Design standardisation is followed by standardisation in production processes and equipment. This is industry maturity. Abernathy et al. [6] define it as follows: "A mature industry is one in which an earlier uncertainty has been replaced by a stability in core concepts, a stability that permits process technology to be embodied in capital equipment or in engineering personnel and purchased in the market place."

Renewal and the Discipline of the Second Curve.

Abernathy et al. [6] argue for the possibility of industry de-maturity. In 1983 they postulated that the automobile industry was being driven into a state of de-maturity by the Japanese challenge and that technological innovation was once more becoming a visible competitive imperative. Now, in 1997, it is quite clear that they were correct.

Baden-Fuller and Stopford [21] also identified a number of companies in the mid 1980s that "had peered over the abyss of looming failure and managed not only to pull back in time, but also to find new paths to sustainable growth." They argue that maturity is a state of mind and that rejuvenation of mature businesses is possible (but not easy) through the active will and actions of management.

Handy [16] provides a useful perspective on renewal and rejuvenation in the context of the Sigmoid curve: "The secret of constant growth is to start a new Sigmoid Curve before the first one peters out." This is illustrated in Figure IV.

Handy [16] gives the following advice: "The discipline of the second curve requires that you always assume that you are near the peak of the first curve, at point A, and should therefore be starting to prepare a second curve."

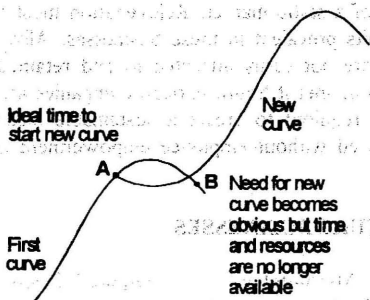
As shown in Figure III mature businesses operate at the apex of the Sigmoid Curve. They are already at or beyond point A on the first curve; they must take action to identify and move onto a new curve or face inevitable decline. This is the renewal challenge.

It must, however, be said that some mature industries operate in environments where it is reasonable to expect that "business as usual" can be sustained for many years to come. Such industries usually involve steady product development albeit at a slow pace.

Renewal and World-Class Organisation.

The tools and philosophies of the renewal of mature businesses are very similar to those advocated for achieving world-class organisation. A brief review will illustrate the point.

Beatty and Ulrich [22] propose four principles for increasing the probability of successful renewal:



1. Create a customer focus through employee training and encouragement.
2. Increase the capacity for change by reducing the organisation's "cycle time" through removal of boundaries. (Process orientation.)
3. Change the corporate hardware (strategy, structure and systems) and software (employee mind set and behaviour).
4. Trust and empower employees at all levels.

Figure IV: Renewal and the Sigmoid Curve [16]

Once management has understood and embraced these four principles they can proceed on the sequence of leadership and work activities illustrated in Figure V.

To illustrate the common ground with the characteristics of a world-class organisation, consider the following five key characteristics of effective companies identified by Blanchard and Waghorn [23]: raving fan customers, committed and empowered employees, financial success, integrity and an environment of continuous improvement.

Mature business renewal and world-class organisation belong in the same philosophical camp as CE. In fact, renewal is probably a prerequisite for a mature company to implement some of the softer issues involved in world-class CE.

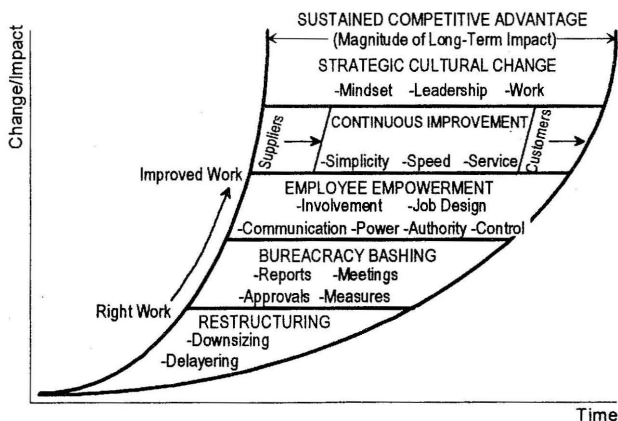


Figure V: A Renewal Process [22]

- Lean operations.
- Price and margin, not volume and share.
- Achieving best practice.
- Appointing tough operating managers.
- Rejuvenation (renewal).

Tough operating managers are needed to run a lean operation which in turn is needed to squeeze every ounce of margin from a stable share of a static market. Rejuvenation must be achieved within the financial and human resource limits prevalent in these businesses. Also needed are freethinking, entrepreneurial managers that are not easily attracted to and retained in mature businesses. However, this challenge needs to be met if South African companies are to achieve the best practices and levels of innovation required to create a sustainable niche in export markets. Truly lean operations are not realised without employee empowerment and process oriented thinking.

5. PRODUCT DEVELOPMENT IN MATURE BUSINESSES

Required Characteristics of a Development Methodology. The required functionality of a mature industrial product changes slowly. The key drivers of development are: manufacturing costs, operating costs, environmental impact, quality and reliability. In essence, the product must provide the same function but at lower cost with improved overall performance.

Product development is therefore confined mainly to enhancements, derivatives and new product platforms. A particular product design may have a life of 10 to 12 years before it is necessary to introduce a completely new design. During this time there will be many minor enhancements and possibly one major redesign.

Maintainability and logistic requirements are simple. Due to the maturity and wide application of these products there is normally a well developed repair industry which is able to purchase the same technology as the original manufacturers and reverse engineer many of the spare parts that are needed.

Renewal Challenges.

Goold [20] identifies eight parenting opportunities for a parent company to add value to the mature businesses in its portfolio.

Of these, the following have particular relevance to South African companies seeking success in export markets:

Therefore fast track development is not a primary concern and neither is design for supportability although neither should be neglected.

Design for Manufacture and Assembly (DFMA) is of critical importance. With the primary goal being reduction of the manufactured cost it is essential to optimise the balance between material and labour costs and preferably reduce both. The dominant influences in DFMA tend to be reversed. In high technology products, the emphasis is on processes that enable new product functionality. In mature products, the emphasis tends to be on designs that enable new streamlined processes. In fact, because the maturity of the product allows little scope for competition on the basis of product functionality, the main source of competitive advantage is manufacturing excellence (see Figure VI).

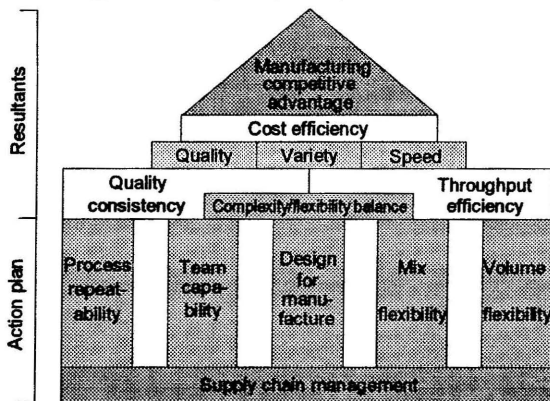


Figure VI: The Pillars of Manufacturing Excellence [24]

Most importantly, it shows a closer match between the requirements for mature product development and CE than between the former and SE.

The authors propose that the correct approach to product development in this context is to adopt CE and incorporate certain tools and features from SE as appropriate, in particular, CE users will benefit from a good understanding of the whole system, whole life-cycle principles of SE. CE and SE have many tools in common but a few are unique to one methodology or the other. However, this does not mean that they cannot be used with both SE and CE. For example, CE can benefit from the use of functional analysis as a tool for value analysis.

Proposed Development Process. The following process represents a combination of CE and SE pitched at an appropriate level of complexity for mature product development. Figure VIII shows the proposed phases and baselines adapted from SE [13,15] with the required element of process concurrency applied [3].

The activities during each phase would include the following [11,13]:

Product Requirements definition.

- Identification of need.
- Appoint a small, multidisciplinary pre-concept team.
- Feasibility study.
- Market research:
 - Customer requirements.
 - Potential sales.
 - Competitors.

The requirements for mature industrial product development are tabulated and compared with the features offered by CE, SE, renewal of mature businesses and world-class manufacture/organisation in Figure VII.

The matrix shows clearly the common ground between, and different biases of, CE and SE. It also shows that CE is very compatible with renewal and world-class organisation.

Concepts and Philosophies	Management Technique				Mature Product Development
	Concurrent Engineering	Systems Engineering	Business Renewal	World Class	
Process concurrency /orientation	✓✓✓	✓	✓✓	✓✓✓	✓✓
Cross-functional teams	✓✓✓	✓	✓✓	✓✓✓	✓✓✓
Strong customer orientation	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓
Whole system approach	✓	✓✓✓	✓	✓✓✓	✓✓
Whole life-cycle approach	✓	✓✓✓			✓✓
Continuous improvement	✓✓✓		✓✓✓	✓✓✓	✓✓✓
Incremental development	✓✓✓		✓✓		✓✓✓
One-of-a-kind projects		✓✓✓			
Handle complexity		✓✓✓			
Supplier relationships	✓✓✓	✓	✓✓	✓✓✓	✓✓✓
Customer involvement	✓✓✓	✓✓	✓✓✓	✓✓	✓✓✓
Top-down, bottom-up design	✓	✓✓✓			✓
Documented dev. process	✓✓	✓			✓✓✓
Formalised and rigorous process	✓	✓✓✓			✓
Detailed & formal project planning	✓	✓✓✓			✓
Employee empowerment	✓✓✓		✓✓✓	✓✓✓	✓✓
Bureaucracy bashing	✓✓		✓✓✓	✓✓✓	✓✓✓
Leadership vs. management	✓✓		✓✓✓	✓✓✓	✓✓
Flexibility	✓✓✓		✓✓✓	✓✓✓	✓✓
Stage gate processes	✓✓✓	✓✓✓			✓✓✓

Figure VII: Concepts and Philosophies Matrix

Conceptual Design.

- Expand pre-concept team as required.
- Generate the following project specific policy/objective statements:
 - Marketing strategy.
 - Design objectives.
 - Manufacturing philosophies and objectives.
 - Service/spares policy.
- QFD - House of Quality.
- Generate and evaluate alternative product concepts using Pugh concept selection matrix.
- Prepare financial model/capital justification.
- Establish resource requirements and full project team.
- Generate a project schedule.

Preliminary Design of Product Range.

- Appoint a full multifunctional project team.
- Firm up conceptual design, trade-off and optimisation.
- Establish rough designs, salient dimensions, etc. to rationalise and optimise the entire range
- QFD - Review House of Quality.
- QFD - Design Matrix.
- FMEA.
- Early prototype of high uncertainty items.
- Early investigation of any proposed new manufacturing processes.
- Identify tooling requirements.

Detailed Design.

- Design for functional capability (performance).
- Design for manufacture and assembly.
- Design for reliability, maintainability and reparability (including FMEA).
- Design for manability.
- Design for economic feasibility.
- Design for social acceptability.
- QFD - Review Design Matrix.
- QFD - Parts Deployment Matrix.
- Specify materials and select suppliers.
- Build, test and evaluate prototypes
- Field trials.

Industrialisation.

- QFD - Process Planning Matrix.
- QFD - Production Planning Matrix.
- Design and prove manufacturing processes.
- Manufacture and prove tooling.
- Generate documentation.
- Finalise marketing plan.
- Prepare product launch.
- Train manufacturing and sales staff.

Production.

- Performance evaluation of tooling and processes.
- Detailed evaluation of test results.
- Modifications and minor improvements to design and process.

Operation

- Monitoring of early units on site.
- Modifications and minor improvements to design and processes.

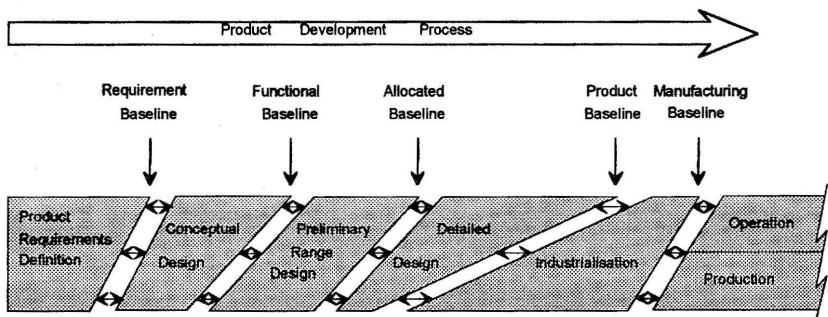


Figure VIII: Baselines with Process Concurrency

The pre-concept team would typically comprise one person from each of the following departments: design engineering, marketing, manufacturing, service and possibly finance [4]. Once full project approval has been granted (conceptual design complete) the team should be expanded to include members of purchasing, quality assurance, key suppliers and possibly customer representatives. A project manager would also be appointed. Go/Kill/Hold/Recycle decisions would be taken after baseline reviews by an executive improvement team (EIT) acting on the advice of a technical review board (TRB). It is essential that this process be documented as part of the company's quality procedures. Documentation should also cover the tools,

outputs, configuration management and revision control, design checklists and the authority of the EIT, TRB, project manager and/or team leader.

Implementation. The implementation of a CE based development process requires a change management process to cover the “corporate software” aspects needed to successfully implement multidisciplinary effort and parallel processing.

Kotter [25] provides a generic eight step process for organisational transformation. Clausings [5] offers a framework that uses these eight steps but presents them as two key enablers and four steps:

- Enabler 1: A significant emotional event is required to create a sense of urgency.
 - Enabler 2: Strong top level leadership with an absolute commitment to change.
1. Awareness (Create and communicate a vision).
 2. Education (Empower others to act on the vision)
 3. Pilot projects (Plan for and create short term wins).
 4. Integration and institutionalising (consolidating improvements and institutionalising the new approaches).

6. CONCLUSIONS AND RECOMMENDATIONS

Conclusions. The title of this paper poses a question which can now be answered. Both SE and CE are applicable to the development of mature industrial products but CE is the more appropriate methodology of the two. In the process of tailoring CE to the needs of a mature business it is feasible and advantageous to include those elements and tools of SE that can add value to mature product development. In particular, the SE concepts of whole system, whole life-cycle and cost effectiveness should be regarded as essential education for the team. Product enhancements are ideal mini-projects for practising the tools and sub-processes of CE.

It has also been shown that CE shares many concepts and philosophies with the management techniques of mature business renewal and world-class organisation. In the authors’ view any South African manufacturing company seeking to make sustained inroads into export markets needs to embark on the path to renewal with the objective of achieving world-class status. The implementation of CE could be successfully incorporated as part of a renewal strategy.

Recommendations. Every manufacturer of mature industrial products should be seeking to ensure that they are growing their ability to compete profitably. This requires a two pronged attack. Firstly, even though the product and the market are mature, they are not static and innovative product development is required to ensure that changing or unmet customer needs are identified and satisfied ahead of the competition. Secondly, a continuous effort to drive down costs is required.

In order to mount this two pronged attack, such businesses must run a lean operation, applying world-class principles in the management of the business. If these principles are not already in place, an organisational development effort is required (best named renewal) that must include the introduction of a “Total Quality Development” process, such as that presented in this paper.

Further Research. There is a need to research product development practices in mature businesses manufacturing industrial products in South Africa and to benchmark these practices against similar industries abroad. This research should also cover general management practices to place the product development process in perspective. In particular, the link between renewal/rejuvenation of mature businesses and the implementation of concurrent engineering needs further investigation.

The Last Word. In the final analysis it is up to the management of individual companies to study the available management techniques, their concepts, philosophies and tools, to consult with the consultants, to benchmark against their competitors and then to determine their own destiny and the best route to securing long-term financial success. Will they find their second curve? Or will

they remain trapped in the first curve, to pass through the agony of decline and ultimately closure of the business?

The choice is theirs!

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