Importance of design management in general engineering

Although Design Management per se is not a new concept, the renewed interest and application as a trending discipline in itself combines traditional systems engineering principles with design and business principles to find the most suitable solution to a specified problem. Although the "new" interest focuses more towards strategic management and problem solving, the generic nature of the principles is visible in the increased application to and success achieved in both traditional engineering as well as non-engineering fields. It is even predicted that good design management practices will become the distinguishing factor between highly competitive businesses i.e. leaders or followers.

The success of any business is determined by the competitiveness of the products or services being offered compared to the available alternatives. The important principles related to engineering are well published and not at all new, yet often resisted despite their proven success. One of the most notable examples in history is the resistance to acceptance of the business principles advocated by Edwards Deming, an American engineer being credited with being the inspiration to the Japanese Miracle of 1950 - 1960. Despite awards for his contribution to the Japanese economic recovery during the 50's, his work only started to gain American recognition around the time of his death in 1993.

As qualified statistician, Deming was, already around 1930, one of the first to move towards the application of statistical methods to industrial production and management in an engineering environment. His focus on improved quality in manufacturing resulted in increased productivity and a significant increase in market share.

Deming's philosophy is summarized as:

"Adopting appropriate principles of management, organizations can increase quality and simultaneously reduce costs (by reducing waste, rework, staff attrition and litigation while increasing customer loyalty). The key is to practice continual improvement and think of manufacturing as a system, not as bits and pieces (The Deming Institute)"

Japan's ability to produce high quality reliable goods at competitive cost resulted in economic pressure on North America and Western Europe. Re-examining the techniques of quality control in an attempt to once again become competitive resulted in the concept of total quality management taking root. However, TQM was only coined around the mid 80's after a recommendation to accept Deming's teachings to improve the US Navy's operational effectiveness (ASQ). The success saw acceptance by industry to recapture markets from Japan and also remain competitive when bidding for contracts. Although no specific definition exists (Holmes, 1992), the key concepts of TQM, as defined by a study by the US Navy (Houston, 1988), include:

- "Quality is defined by customers' requirements."
- "Top management has direct responsibility for quality improvement."
- "Increased quality comes from systematic analysis and improvement of work processes."
- "Quality improvement is a continuous effort and conducted throughout the organization."

The strong drive to focus on maintenance to reduce operating cost resulted in maintenance decisions favoring maintenance cost reduction resulting in increased pressure on sustainable reliability. This resulted in different approaches to consider the impact of maintenance decisions on overall life cycle costing resulting in the term Asset Management to maximize value-for-money and satisfaction of stakeholder expectations (TWP 2014). The need was subsequently identified for standardization of the Asset Management process resulting in the development of ISO 55000 in January 2014 as a guide to optimal management of physical assets (IAM). It addresses the integration and optimization of all aspects of the asset lifecycle including design, acquisition, commissioning, operation, maintenance, improvements and ultimately decommissioning and disposal.

ISO 55001, however, addresses asset management in general. Applying the asset management principles to engineering equipment specifically has subsequently resulted in the term Physical Asset Management (PAM) or other variations of it.

In essence Physical Asset Management is associated with reducing life cycle cost of equipment. As the maximum short term benefit is realized through improving operational practices, it is often incorrectly assumed to be related only to maintenance and condition monitoring during operation. However, these are primarily post commissioning activities impacting, on average, a mere 10% of the total life cycle cost (AMC 2009). Reducing life cycle cost, however, includes much more than merely maintenance and condition monitoring. It builds on RCM (Moubray 1997) which integrates Maintenance Engineering and Reliability Engineering to reduce over life cycle cost through improved operation and maintenance as well as improving the design.

Maximizing value

In order to understand the principles of physical asset management it is important to understand the relevant objective. Although there may be various objectives, in business there is generally only one objective, to *maximize shareholder value over a predetermined period of time* (Mauboussin, Atwater). This "value" can mean different things to different people under different circumstances, but it is generally translated as maximizing the return on investment. This is often seen as increasing revenue and decreasing capital or maintenance costs. This has resulted in businesses often incorrectly assuming a lower capital cost to translate to increased value. However, value is realized by increasing the ratio of revenue to cost. The optimum point may actually be achieved by increasing these costs or lowering the revenue if this increases the revenue/cost ratio when considered over the total life of the investment.

Maximizing "value" should therefore be a design function aimed at finding the most suitable solution for achieving the best result for a specified goal. The decision is therefore not per se governed by the functional design, appearance or operation, but by the impact the solution has in meeting the objective. The capital cost is normally negligible compared to the cost of unplanned downtime impacting production. A key parameter in reducing life cycle cost is therefore availability.

Simplified, availability can be defined as *"The potential to generate income when the opportunity arises"*. In order to generate income, equipment has to be ready to operate when the opportunity presents itself. However, having equipment available (ready to perform) without an opportunity cannot produce revenue. The challenge therefore is to ensure that the asset is managed in such a way that it is ready for use when required and maintained when not required, i.e. planned maintenance.

Availability is also accepted to be the product of reliability (how often it fails) and maintainability (how quickly it can produce again after failing) (o'Connor). In order to maximize potential to generate income the challenge is therefore to maximize this product at the lowest overall cost. Condition monitoring is often applied to predict and minimize downtime and thereby reduce maintenance cost. However, both reliability and maintainability are parameters determined prior to commissioning as characteristics of the selected equipment and layout. In order to maximize the availability/LCC ratio it is therefore essential to address these parameters in conjunction with the business objective during the design/development phase.

Design Management

In the past decade design has emerged as process leader in new product development in the drive to link "good design" to "good business" (Liu). This elevated the importance of design management relating to the organizational and managerial practices to obtain good designs through effective processes. The Design Management Institute defines design management as:

"Simply put, design management is the business side of design. It encompasses the ongoing processes, business decisions, and strategies that enable innovation and create effectively-designed products, services, communications, environments, and brands that enhance our quality of life and provide organizational success."(Design Management Institute).

Supporting this definition Design Management focuses on the effective management of resources, processes, procedures and projects (Best). The current trend clearly focuses on "designing" solutions to complex problems outside the traditional understanding of engineering design. Its main focus is identifying ways to produce quicker solutions in an increasingly fast paced commercial environment rather than the traditional engineering design process. Common application inter alia includes industrial economy, fast moving consumer goods (FMCG), architecture and manufacturing industries as well as improved decision making related to public services. Steven Babitch, presidential innovation fellow at the White House during an interview on service design in government (Damood) reiterates the importance of service centered and human centered design as a developing field of practice. Increased pressure for shortened development cycles and response times is, however, as applicable to all disciplines and industries applying traditional engineering aspects at any stage to achieve an edge over the competition. This also holds true for seemingly "non-engineering" industries such as the cosmetics industry where product pricing is influenced by the effective management of the development, acquisition and production processes using traditional engineering equipment. The aim of this paper is therefore to sensitize readers as to the value of integrating the traditional engineering design approach with the current trends of finding the most suitable business solution.

Driven by the consumer goods industry the term Design Management addresses the integration of business objectives with design objectives to result in products satisfying both customer expectations (competitive pricing, comparable performance, reliable, cost effective, aesthetics) as well as company business strategy (increased market share, time to market, ROI, warranty and liability risks). Investigating the traditional systems engineering principles of failure mode and effect analysis (FMEA), root cause analysis (RCA), Reliability Centered Maintenance (RCM), design review, house of quality and requirements engineering reveal these principles to be as applicable as they are for application to the far more complex defense systems. Although applicable, the highly competitive market with relatively short life cycles requires completely different dynamics than that of the defense industry. The awareness for optimizing overall life cycle cost through good design becomes a competitive tool to gain an edge over the competition.

The evolvement of physical asset management has resulted in numerous activities largely focusing on more effective operational tactics, i.e. condition monitoring, maintenance engineering, etc. However, as mentioned before, the selected equipment in essence determine the potential of what can be done to manage the operational cost and reduce the total life cycle costs. Managing modern engineering designs should therefore include the process of selecting the most suitable technical solution to satisfy business objectives as early as possible. Should the objectives change later in the project, the selected solution may no longer be the most suitable which means that design management needs to interactively manage the both business and technical sides of design.

Addressing a problem or change in scope becomes increasingly difficult and costly the deeper into the project it is required (Barnard). This increase has seen an exponential growth as system complexity increase. This justifies spending additional time early on in identifying the correct objective. Applying systems engineering principles to traditional engineering development projects have shown their value in fixing design requirements early on in order to reach the right solution first time (Gause). The biggest discrepancy between the defense industry and commercial industry is that the defense industry is driven by safety and impact and longer development cycles and not by commercial business targets such as time to market and return on investment. It is, however, exactly the reduced time and budget of the commercial industry that requires more attention in identifying the correct solution to drive towards the first time.

Based on the above, important tool sets and inputs to effectively manage the design process in a commercial engineering environment inter alia include:

- Company and project objectives
- Systems thinking
- Reliability Engineering
- Physical Asset Management (including life cycle analysis)
- RCM
- Simulation and optimization
- Objective decision making
- Design Reviews
- Integration
- Training

Objectives

As suggested by the definition for Design Management an essential input to the design management process is the company and project objectives and how they are to be measured. Too often random traditional values are still measured that do not necessarily contribute to early identification of eminent failure while missing the essential measurement that will tell when change is required. In general, good practice is to identify no more than six essential measurements (XXX) that will ensure that the objective will be achieved and supply an early indication of any variation that may jeopardize doing so. As far as possible measures should be leading indicators allowing proactive action to eliminate or mitigate any negative impact before it happens.

Systems Thinking

The first essential tool in design management is effective systems thinking. Too many projects run over budget and time due to solving of the incorrect perceived problem. Systems thinking offers a creative and systematic approach to identifying and solving the right problem first time. Numerous companies have proven the success of effective systems thinking for solving both complex as well as simple engineering problems. However, traditional approaches to problem solving often resist systems thinking due to the perceived effort and delay in producing artifacts. It requires time which is often deemed secondary to schedule or hardware. However, the less time and money is available, the more important effective systems thinking becomes in solving the right problem first time. At the core lies the concept that no problem exists in isolation. Any problem forms part of a larger problem, but also consists of multiple lower level problems that needs to be solved to achieve a workable solution. This means the solution can also not be found in isolation. This is also reiterated by Deb Mrazek, founding partner of Curiate, a consulting company advising Fortune 100 companies in various industries and governments globally on "designing" user centered strategies for creative problem solving (Curiate). Challenging engineers in industry during postgraduate courses over a number of years indicated the general consensus to be that engineers are generally taught the importance of doing things right, but are seldom taught to do the right things. Although a relatively simple mind shift to make, it generally does not come naturally to accept that a 50% accurate right answer is more usable than a 100% accurate wrong answer. Although accuracy is always important, it is outweighed by the need to apply your effort to the right solution.

In order to reduce process waste the manufacturing industries developed the Lean principles which, due to the success, also found its ways into IT and other non-manufacturing environments (Mueller et. al.). This is especially useful for developing user centered products or services where conditions are extremely uncertain or dynamic. A more recent trend is to replace Lean with design thinking. The main difference is that Lean does not have a clear beginning or end as the circular process suggests that steps are executed continuously and repeatedly whereas Design Thinking suggests a linear approach. The main difference is that Lean focuses more on startups where the initial idea/solution is already defined whereas Design Thinking is focused on finding the innovative idea for solving the challenge. The two approaches can therefore be complementary, but neither can be applied without a clear understanding of the context of the actual problem as defined by Systems Thinking.

Reliability Engineering

Although not a new concept, Reliability Engineering is still often confused with Reliability and subsequently discarded as irrelevant due to the perceived discrepancy between reliability figures stated in literature or achieved through simulation and the actual values obtained during operation or testing. To ensure that the reader is aligned with the author, the difference is quickly highlighted.

- *Reliability* involves the use of statistical methods to predict the probability of equipment to perform the intended functions under specified conditions for a specified period of time (oConnor). Reliability therefore is simply a figure associated with a very specific condition only i.e. that used during the calculation. Operating away from the simulated condition, which is more common than not, renders the specific value useless if there is no indication of the resulting trend due to the change. Practical application of reliability figures is therefore only valuable when comparing multiple scenarios under similar conditions and should therefore not be misused as target values.
- *Reliability Engineering* in turn involves a process using relevant systems engineering principles together with statistical data to find the most suitable solution to ensure that equipment will perform in a predictable manner when you need it for as long as you need it (oConnor). This does not necessarily mean the cheapest product or the best performance, but the one that satisfies the customer requirements/expectations the best. As it describes a

process for ensuring satisfactory performance for the intended life of the product it is completely different to merely deriving a figure and clearly forms an essential component of design management.

Physical Asset Management (including life cycle analysis)

Physical Asset Management can be described as the effective balancing of cost, opportunities and risk related to capital equipment, fixed or non-current (IAM). It covers the whole life cycle from concept to disposal and includes optimizing replacement/repair decisions throughout the life of the equipment or plant. Although this is often associated with condition monitoring, it includes more than only condition monitoring. It is a systematic approach to improve decisions for optimizing selection, deploying, operating, maintaining, upgrading and disposing of assets to sustainably achieve the stated business objectives (Komonen). It therefore requires more information than only the actual condition of the equipment. It requires a sound understanding of the overall life cycle of the equipment, which is impacted by design decisions, as well as the business objectives and market trends. Physical asset management therefore is the art of making the right decisions with respect to inter alia life cycle cost, risk and business continuity (IAM) which also includes sound decisions related to the technical performance aspects of equipment, i.e. the design.

RCM

Another important tool in the design manager's toolbox is Reliability Centered Maintenance or RCM (or RCM II) (or PMO when applying to brown field applications). However, as with all other systems engineering tools, templates cannot be blindly applied to an asset. It is essential to understand the basic RCM principles, how to apply them and potential pitfalls. It is therefore important that the analyst is formally trained in these principles and then mentored in order to develop a thorough understanding and be conversant with the seven questions of RCM when developing a process relevant to the specific project or company. There are numerous variations being applied in order to reduce the effort, but if the seven questions are not answered in full the outcome could result in an incorrect decision. Of particular importance is the question of "how does the failure matter" as the answer will determine the risk and therefore the most suitable action required to minimize the overall risk. As physical asset management awareness increases, the scrutiny to ensure that diligent and technically correct processes are used to determine the most suitable maintenance program will also increase. It therefore makes perfect sense to adopt the RCM principles during design as it has proved to be the most powerful tool to identify proactive work requirements.

Extremely important is not to discard a possible failure as "unlikely" or "not foreseeable". The question is, can it happen and what are the consequences if it does happen. Only once the risk has been proven to be negligible may it be stated that no action is required. However, the potential failure is still listed in order to ensure traceability and prove due diligence.

Objective decision making

Another essential component of effective design management is objective decision making in order to remove bias and ensure objective and repeatable outcomes. Solutions are often a result of the mindset through which the problem is formulated and is governed by a self-regulatory system (King et. Al.). Decisions will therefore be impacted by the focus of individuals to benefit the team/company or themselves. The role of the Design Manager is therefore to manage the inputs from the various role players to find the most suitable objective solution despite the variation in focus of the different team members. Systems engineering has developed various methodologies supporting objective decision making which inter alia includes methods to identify as close to optimal solutions as possible including multiple-criteria decision analysis unifying various best practices for engineering decision making. Engineering practices used to improve decision applied include market analysis, requirements analysis, scenario planning, quality management and specifications. Applied correctly objective decision making results in repeatability of the outcome irrespective of personal preference. The importance of effective engineering decision making is evidenced in the vast expanding field of decision engineering. Many tools such as design thinking, critical thinking and logic are ancient. However, the development of technology has opened numerous options that did not exist in the past to develop into decision intelligence as a field in its own to understand needs of clients and markets and the required resources to effectively address it (DFC). A study by Prat and Zangari interviewing 61 executives and thought leader in various industries show that the need to visualize, communication and time to make a decision are still most important complicating factors in effective decision making (Pratt). Thomas Davenport of Babson College also confirms that the time has come to reengineering our decision making (Hopkins) towards an increased focus on decision making. He indicates that the second most important aspect in improved decision making after improved analytics is a change in leadership culture. This raises the need for managerial support for developing more effective tools in presenting the problem effectively. However, changing leadership culture from making decisions to asking for help to make improved decisions is an essential, but politically challenging mind shift.

Simulation and optimization

An important tool offering increasing potential as technology develops is that of simulation and optimization. The value is also evident in the increase in simulation-based engineering design. This not only reduces the risk of not meeting expected performance, but also reduces overall budget and schedule significantly. However, the biggest value of simulation is not the actual values generated, but that it enables an improved understanding of the process and the possible alternatives. Although sometimes costly, the cost outweighs the cost of rectifying an error later on by factors of magnitude. Selecting and deriving appropriate models will depend on the relevant business and project objectives. Multivariable optimization techniques allow for significantly reduced simulation time and cost, allowing simulation of complex interactions to support decision making. Understanding the driving parameters of the objectives allows for improved optimization at a fraction of the cost of the repeated experiments of the past. Design Management therefore includes understanding the problem at hand to sufficient detail to allow effective simulation and optimization during the design process supporting the integrated business and project objectives.

Simplified simulation models can offer rapid and effective estimates during front-end engineering design (FEED) where the customer needs are still flexible. This allows rapid response to variations reducing the risk and time required to fix plant layout or prepare a quote or tender. Detailed design simulation is then only entered into once the tender has been successfully secured or the user requirements have matured to a level where recalculation will be unlikely. Using such simplified models it is important though to also understand and not exceed the limitations of the simulation.

The value of implementing simplified models during the FEED phase can be seen in the following case studies. In each of these cases systems thinking was applied to first identify the actual problem and the driving parameters after which a simplified model was developed using Mathcad. The reason for using Mathcad was that the design logic is easy to follow and discrepancies in the design logic is easy to identify and correct. It also simplifies the modification process should additional features be implemented even if it is not done by the original model developer. In addition it can also serve as a training tool for new employees.

Case Study 1 – Conveyor belt design

Working in a mining infrastructure development environment conveyors are common items to be designed. This is generally done using advanced conveyor design packages. Due to the cost of such packages this function is often outsourced. Outsourcing the design results in increased lead times often resulting in settling on a less than optimum layout in order to move forward. In order to decide on the most suitable conveyor configuration it is important to understand the impact of varying the driving parameters. Outsourcing leaves the team at the mercy of the contractor to supply guidance.

Two conveyor models were developed using different approaches and compared with results obtained from commercial packages. Once satisfied that the results were acceptable for the purpose, life cycle cost drivers were identified and implemented. The models allowed a preliminary design within 10 minutes allowing on-site evaluation of various options. This allowed what-if analyses allowing guidance to the customer as to the most suitable solution. Where possible the models included options for design considerations identified during previous projects. Having an in-house model allowed additional features to be added for the specific customer. The approach allowed multiple options to be considered in order to finalize the most suitable layout. Calculations offered improved information during design reviews allowing improved evaluation and interaction with the contractor on the final technical solution proposed.

Some of the results showed that if the required life is long then the operating cost could justify the higher capital outlay for improved reliability. Running a wider belt at a lower speed requires a smaller motor for the same production. The wider belt requires wider idler sets which results in a higher initial capital cost. However, this might be justified for a longer life cycle where the increasing cost of electricity over the life of the conveyor could exceed the additional initial capital cost. It also offers and option for increasing production at a later stage. Important to note though is that a design is based on the inputs supplied at the time limiting the potential for life extension or performance improvement if this was not included.

The life expectancy and production are determined by the business strategy.

Case Study 2 – Stockpile design

The second case study looked at the design of a stock pile. Integrating the stockpile volume in four different ways resulted in the same simplified equation representing the full stockpile volume. However, depending on the integration used the remaining volume can be determined analytically based on the harvesting technique employed to recover product from the stockpile. Using a kidney shaped stockpile with a rotating stacker results in a kidney radius impacting the footprint of the storage area to be prepared as well as the length of the stacker. The volume is impacted by the height and the length of the stockpile. Knowing the economic relation between the stacker size, stock pile volume and storage footprint it is possible to optimize the configuration for minimum cost for the product to be stored. Once the model is available it is easy to recalculate the required sizes for any variation. Should the business strategy require a longer life this may require a shorter stacker due to maintenance costs resulting in a larger sweep angle resulting in a larger storage footprint to accommodate the same volume. Alternatively, if a smaller volume is accepted it require more regular replenishment in smaller quantities which may incur other costs.

Developing such models may seem expensive, but the benefits of serving the customer with timeous information allowing informed decision making builds confidence which could impact repeat business.

Case Study 3 – Tank design

A third study included a model for large storage tanks. Considering all the aspects of tank design it allows for a quick evaluation as to the most suitable tank yard configuration. Using knowledge of tank manufacturing and limitations as well as economic models it becomes a relatively simple task to adjust tank sizes (diameter and height) to determine required or suit available footprint area before finalizing layouts in different environments. Reducing the interaction with the tank designer reduces the time delay significantly, especially when adjusting the layout regularly to suit plant requirements. Once the design stabilizes the model offers a design that is generally close to the final design. With the requirements determined the tank designer is supplied with the information once. Initial calculation then serves as a basis to compare the final design to for any variations. This reduces the risk of oversight.

Important though is not to confuse the model with detailed tank design software. The model development cost significantly less than tank design software as it was intended to serve as a preliminary estimation tool to support business decisions on plant configuration and not to replace the tank designer.

In all three case studies the process was to first identify a suitable model, then identify the main parameters driving the sound business solution and then optimizing them using multi-variable optimization.

Integration

As with the other historical drives before, it is also easy to discard all other theories and methodologies and only push Design Management as the be all and end all. This is not the idea. It merely focuses on something different in the total process. However, it formalizes a very important aspect of the engineering and physical asset management processes. As important as it is, it also requires the support of management as well as all the other disciplines and functions to ensure that its full potential is realized (Deming 1982).

The Design Management Europe survey identifies a Design Management Staircase (Kootstra 2009) indicating four levels of design management maturity found in companies. It links the maturity levels to the success potential of companies and indicates the five important factors to be:

1. *Awareness of benefits* – Management's attitude towards design (a critical factor)

2. *Process* – Pursuing a robust and effective design management process
3. *Planning* – Strategy for design, articulated in business plans and communication
4. *Expertise* – Experience of staff and range of tools applied
5. *Resources* – Investment in appropriate design staff, environment and hard- and software

The study continues in the developing of a method to score the company's ability to manage design activities based on 18 questions. A noteworthy difference between innovation leaders and innovation followers, a distinguishing characteristic of successful companies, is the "definition of clear design objectives" (62% vs 39%). A surprising outcome was that there was no difference between manufacturing and non-manufacturing companies. Deployment of design management is more effective when design planning forms part of the long term strategic planning as a dynamic process driving business.

In order to anticipate the impact of decisions on business it is essential to understand the relevant industry and relevant business principles as well as the company objectives and customer requirements. Developing the skills and expertise to predict the impact of design decisions allows considering different options and identifying the most suitable solution. Management, however, has to be open-minded to potentially change the business objectives if this would increase overall value. It also requires management support to change processes and procedures if identified to be restrictive. The focus should, however, include a strong drive to satisfy customer requirements and include them in the design process.

Clear company executive strategy is important to evaluate design objectives, e.g. is the intent to actually start manufacturing as well or simply remain a distributor, is the product supporting the company image to be a cheap replace-and-discard item or a longer life serviceable item, or is the aim low cost mass turnover or high quality low turnover? These are important management decisions as to what the company strategy is which cannot be answered by the design team. However, design decisions are influenced by these objectives as well as input from the designer (i.e. what will it cost, how long will it take etc) and the operator (how will it be operated, what is the cost of downtime, how often does it break, operating schedules, etc). Effective decision making can, however, only be done if the impact of the decision is truly understood and design management offers an important tool in achieving this.

Continuous improvement is also essential in order to remain competitive. Operations/customer feedback is therefore essential in identifying possible areas for improvement, both as to upgrading existing products/services as well as developing new products/services. This can include design changes to result in improved equipment or equipment replacement to result in more effective or reliable systems.

It is furthermore essential to understand the impact of operational cost on the company objective. Too often maintenance departments are put under pressure to reduce expenses thus eliminating options that could improve the overall value, but at the cost of the maintenance budget. The reason for this is that the resulting savings are not reflected in the maintenance budget, but in the budget of the serviced department.

An extremely important factor in design management to ensure that the selection of the most suitable solution is based on scientific evidence including risks associated with both company and customer objectives. Research shows that only about twenty five percent of companies actually apply a professional selection process. Quite often the design is selected by a dominant manager or team member without considering all the important parameters (Kootstra 2009). Less than twenty percent of companies have formal procedures in place to assist in decision making based on investment appraisal and risk assessment.

Managers therefore need to understand how long it takes to arrive at an adequate design and plan this into the initial phases of the project. Not doing this not only may lead to a less suitable solution, but also increases the risk to the company with respect to budget, schedule, non-performance and even warranty claims. The essential ingredient is, however, an appropriate corporate culture being enforced, or at least supported, by senior management.

Although it is not essential to have the design capabilities in-house (it will depend in the type of business), it is important to have the design management capabilities in-house as to ensure that the required interaction is maintained to ensure that company objectives and customer expectations are met (Banks 2009).

Implementation

Given the increased pressure on creating value and limiting overheads increases the need for good design management. However, motivating the expense requires to demonstrate the value to the business before investing. As with Quality Management, successful implementation requires an understanding of the importance and value by senior management. Stephen Emmit gives a good description of the role and importance of design management in his book Design Management for Architects (Emmit). He indicates that although not every member of the team should be a business executive, it is important that team members understand the commercial environment they work in and the value of managing design consistently and efficiently. Design Managers act as the integrator between the business objectives, the customer requirements and the technical product performance and therefore are responsible for all aspects of the design. Although it requires business omen and project management skills, the role is defined by a strong passion for design quality. As team members all have a specific role it is easy to lose focus of the essential interaction with other members or their roles. The difficulty is increased as pressure and design complexity increases. It is the role of the Design Manager to coordinate all design activities into a consistent process. The main purpose of the role is to allow the different team members to perform the functions they are good at i.e. engineering, design, project management and business. Effective design management requires a broad understanding of a wide range of discipline specific knowledge and an ability to make sound strategic decisions. It requires interaction and communicating strategic decisions with a wide range of team members ranging from business executives, program managers, designers, contractors and customers. These are generally culturally different environments due to the different foci. It is therefore essential that the team experiences senior management support for the role.

In smaller companies the role can often be fulfilled by the owner of the company. However, as the company grows and the complexity of projects increase the necessity for effective design management also increases. The role of a design manager is often perceived as less important due to the interactive nature being perceived as a function that any team member can fulfill. The delayed benefits of customer satisfaction, improved staff morale and successful project delivery is difficult to motivate during the early stages of project and therefore requires a supportive culture understanding the value. A major benefit often overlooked is that the design manager can apply relevant skills to multiple projects. It is this synergy between projects that increase the potential for success. The aim of the Design Manager therefore is to make the design process more profitable without compromising the quality of the technical work delivered.

Implementing design management initially generally requires a change in culture. This necessarily also initially requires a high level of interaction between the Design Manager and the other disciplines as the Design Manager comes to terms with the different cultures within the company in order to create effective interaction. Understanding the cultures is essential in understanding how to implement strategies to improve the design process. It is important that management understands the required dynamics and allows the necessary interaction to build confidence between the relevant parties.

Educating towards the mind shift

In order to ensure a company-wide understanding of the essential interactions, principles and benefits it is important that all technical employees are educated in the basic principles of design management. The research by Kootstra indicated a significant group of employees do not understand the essential basic principles of design management and are unaware of the impact of intellectual property rights to their business (almost 40% do not make it past Level 1 on expertise).

Training has, however, also been proven to have a half-life of 2.5 years when applying the knowledge on a regular basis (McNair 2011). This means that, even when having had formal training, people should be retrained every two years to ensure that they are still applying the principles correctly and have not drifted into simplification of the process/principles to unacceptable levels. This period should be reduced in cases where the knowledge is not applied on a regular basis.

Summary

Although there is a renewed interest in Design Management, the principles applied are nothing new. However, increased application to industries traditionally perceived as non-engineering industries currently focuses more on the fast paced commercial business process design i.e. developing strategy etc. and less so on the technical side. However, success can only be ensured with a sound technical solution supporting the business strategy. In order to develop an effective solution in the shortest possible time it is therefore important to interactively manage all aspects of design to satisfy the business objectives. Traditional systems engineering offers many tools to achieve exactly this although it has been somewhat resisted due to the perceived complexity of longer term development projects. There is, however, no single solution and the level of application complexity of the principles should be adapted to the environment and level at which the relevant company is operating, i.e. supplier, distributor, manufacturer, designer, operator, etc. The aim of this paper is therefore to sensitize readers to the importance of integrating technical decision making with business decisions to find the most suitable solution. Research has, however, shown a lack of understanding of the basic principles involved.

In order to maximize the value of design management companies therefore have to apply an integrated approach to design, driven from the top down. It is essential that operations, engineering and management break down the traditional silos and agree on the most suitable combination of quick, good and cheap to support the company objective in meeting the customer expectations.

The value of design management in maintaining a competitive edge is reiterated by Darragh Murphy (Murphy 2007), a design management consultant, saying

"When all businesses are designing value-added, user-oriented, desirable products it will be those with good design management practices that will be able to stay ahead".

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