The Role of Systems Engineering in Business Planning

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Abstract. Business Planning is concerned with planning the future of an enterprise. It includes the allocation of budgets to particular enterprise activities in order to meet the goals and objectives of the enterprise's vision and strategy. Regarding the enterprise's value generation process, technology development, product development, manufacturing, marketing and sales are consuming essential portions of the overall budget and should therefore be addressed in the business plan. The quality of business planning has a major impact on sustainability and resilience of an enterprise. Changing markets and progress in science and technology set the demand for agility and flexibility in the business planning process with a right mix of proactive and reactive decision making. This paper takes a look on the activities that should be performed before a business plan is released with special emphasis on systems engineering, but also considering marketing, technological innovation, and the product portfolio strategy.

Introduction

Systems engineering addresses the whole system life cycle. From this statement it seems to be obvious when systems engineering starts. But considering the organizational and market context systems engineering is embedded in, the responses given in the systems engineering literature to the following two questions becomes somewhat fuzzy:

> When does the system life cycle really begin?
>
> When and in which context shall the initial systems engineering activities be commenced?

The most conservative answer to the second question is that systems engineering transforms requirements into implemented solutions. This response fits well to the business model in which systems engineering has grown, and is still repeated in recent papers, see for example (Brook and Riley 2012). Companies react on demands for innovative and complex systems. For mastering innovations, technologies have to be progressed. Technology development may be performed with some independence from system development. To some extent this has led to a view that technology development comes up-front the system development (DoD 2008). Other sources prefer to talk more generally about a study period that may include the generation of pre-concepts before the actual system life cycle starts with a concept phase (Forsberg, Mooz and Cotterman 2005). Disbanding the synonymous usage of the terms stakeholder needs and stakeholder requirements in accordance with ISO/IEEE/IEC 29148 (ISO 2011), such views seem to be too simplistic.

Considering today's relevance of systems engineering beyond the traditional application domains, the two questions raised above demand more elaborate answers. Especially, more emphasis has to be put on the market context. This does not mean to support views making an essential distinction between market-driven and technology-driven development as frequently done in the systems engineering literature to point out the differences between commercial and government approaches to business (Rhodes 2002). The business models in the traditional systems engineering application domains are not free of market elements like in the supplier selection process. And, market-driven domains applying systems engineering are not free of technological innovations, of course. Every successful systems engineering endeavor is aligned with the particular market context, and exploits established and innovative technologies efficiently (Schulz et al. 2002).

The ultimate cause for the differences in governmental and commercial business models seems to be the risk share between acquirer and supplier. Traditionally, governments take over risks that are not affordable for industrial companies since individual companies do not have the strength to cope with those risks. The risks taken over by the acquirer then may include the risks that the actual needs of the acquirer and all stakeholder's on the acquirer's side are well communicated and that manufactured products are sold. This business practices have led to a less overall risk awareness in those companies working on public projects. On the other hand, globally acting companies have reached a level of business power today sometimes similar to governmental power. Consequently, governments are willing to divert more risks to those companies. The attractiveness of private-public partnerships provides an indication for this change. But the consequences go even further: The differences between former governmental and market-driven business models are more and more fading away.

This paper aims for a universal business planning process model balancing market and technological innovation drivers. Applying this business planning process model may then more focus on the market or the technological innovation aspects as appropriate. In this context, responses are given to the initial questions: Both, systems engineering and the system life cycle start when product elements are elaborated in the course of the development of the product portfolio strategy. For readability reasons, services and service portfolios are not explicitly mentioned in this paper, but the considerations and conclusions also apply to services.

The reasoning for the proposed business planning process model is developed in consecutive steps. In the first step, the value of life cycle phase models is emphasized in contrast to value stream representations of the systems engineering process. In the second step, the just-in-time principle is examined regarding its importance in systems engineering considering the human motivation cycle as its psychological foundation. Based on these prerequisites a corresponding system life cycle phase model is proposed in a third step. So far, the reasoning builds on and expands the content of a previous paper (Scheithauer 2013). Because the former paper is written and published in the German language, it may be helpful for many readers to find here an outline of its content. The final fourth step is concerned with introducing the business planning process model tying together marketing, the development of technological innovations, and systems engineering as essential pre-requisites for integrated business planning.

Life Cycle Phase Models versus Value Stream Representations

A Discontinuity in the Evolution of Systems Engineering. Life cycle phase models are an important heritage in systems engineering. However, today they are taken as a traditional asset without spending a lot of thoughts on their definition. Considerations on the following topics are rarely elaborated in the current systems engineering literature, for example in the INCOSE Systems Engineering Handbook (Haskins 2011):

(1) How to split the system life cycle into individual system life cycle phases?
(2) What is the purpose of particular system life cycle phases?
(3) Which activities should be performed in particular system life cycle phases?
(4) What are the entry criteria and the exit criteria for each system life cycle phase?

The absence of those discussions does not necessarily mean that there is not somehow a consensus within the systems engineering community about those topics. Surprising is that there seems to be no further need felt for more in-depth discussions of these subjects today.

The reason for today's disinterest in system life cycle phase models may be that system life cycle phase models have become in the systems engineering practice as unpopular as the waterfall model. Other approaches originating mainly in software engineering became much more attractive (Larman and Basili 2003). Incremental and evolutionary life cycle models provide more detailed insight into the engineering activities than a waterfall type model. So far this development may be anticipated as a continuous evolution. But the same story may be told following a complete different narrative as well: There has been a creeping paradigm shift for whom those system life cycle models are defined. Initially, the target audiences for system life cycle phase models were those stakeholders to whom the systems engineers had to demonstrate the status of their achievements like customers, certification authorities, and organizational management. As a side effect they offered also some benefits for the engineers running the projects. The more detailed life cycle models typical for today are directed to provide insight to the systems engineers themselves. But they should still also satisfy the reporting needs of the other communities.

Both audiences exist and need to be served with appropriate views. It should be noted that a proper distinction between those audiences cannot be properly drawn by a segregation of project management from systems engineering management. The distinction is better described between value stream representations of the systems engineering process and system life cycle phase models. Based on current experience it seems to be only of little value trying to mix both types of system life cycle models together. Detailed value stream oriented information may not be interpretable correctly to the project-external stakeholders, and blending in system life cycle phases into value stream representations may limit the expressiveness for the full development dynamics the engineering teams have to cope with. In conclusion, the recommendation is: Neither interpret life cycle phase models as value streams, nor value stream representations as life cycle phase models. Both views have a purpose according to their own rights. However, there is a strong demand for compatibility of the life cycle phase model serving the project-external communities with the value stream representation serving project-internal management.

Value Stream Representations. Value stream thinking is one of the founding principles of systems engineering covering not only the development part, but the whole system life cycle. However, the traditional value stream interpretation in systems engineering follows less strict principles than expressed in lean thinking (Ohno 1988; Womack and Jones 1996 and 2003).

The paper presented one year ago proposed some V-model views that interpreted the V strictly as a value stream representation of the systems engineering process (Scheithauer and Forsberg 2013) eliminating the reminiscence to system life cycle phase definitions. The flow within the overall systems engineering value stream represented by the V is imagined as the hand-over of high quality configuration baselines within the system architecture.

Another paper presented two years ago introduced work product generation sequences as the appropriate value stream representation of the value stream for developing a particular system element within the system architecture (Scheithauer 2012). The link between work product generation sequences and the overall systems engineering value stream is established by configuration baselines referencing the work products contained in a work product generation sequence.

In conclusion, pure value stream representations follow a complementary narrative to life cycle phase models. It is worth to be aware of both narratives, but the content of this paper should be fully understandable without having read the previous papers.

Life Cycle Phase Models. ISO 15288 states that life cycle stages represent the major life cycle periods associated with a system (ISO 2008). ISO 24748-1 adds that the definition of life cycle stages may have a business overtone (ISO 2010). The definition of the system life cycle phase model proposed herein follows these principles. Other descriptions from ISO 24748-1 are ignored, e.g. life cycle stages do not necessarily occur one after another in a time sequence, and in practice life cycle stages are interdependent and overlapping. These statements provide indications of mixing up life cycle phase models with repetitive iterations of the systems engineering value stream. Talking about life cycle stages instead of life cycle phases demonstrates a reluctance to commit to earlier understandings of life cycle phases as time periods following sequentially one after another.

Important for the definition of system life cycle phases is the specific purpose of each system life cycle phase. In a particular system life cycle phase, parts of the systems engineering value stream are executed that may be also re-iterated in other system life cycle phases for two reasons. First, the purpose of the system life cycle phases may differ. Second, an iteration may demand that activities performed already in a previous system life cycle phase have to be repeated in the course of a later one. Implementing small product enhancements during the utilization phase are a common example as they demand updates of work products and configuration baselines that have been established during development originally.

This paper defines the system life cycle phases with respect to the overall system, e.g. the product to be delivered. There are at least two good reasons for this decision:

First, the entry and exit points of each life cycle phase mark major synchronization points of the parts of the overall systems engineering value stream executed from an organizational perspective. This affects the understanding of the system environment, and the development of the overall system and all abstract systems. For the system elements on the implementation level each supplier will set an individual focus on the supplier's own product. Suppliers will therefore define system life cycle phases with respect to their overall system. Note that the terminology applied in this paragraph is fully aligned with the definitions used by the paper on V-model views (Scheithauer and Forsberg 2013).

Second, defining system life cycle phases separately for each abstract system would extend the system life cycle phase model into the domain of the overall systems engineering value stream representation governing the hand-over of information within the system architecture.

Just-In-Time in Systems Engineering

Just-In-Time from a Supplier Perspective. Just-in-time is one of the two lean principles established by Taiichi Ohno who had a leading role in the invention of the Toyota production system (Ohno 1988). The other lean principle stated by Ohno is the autonomation principle. Autonomation does less matter regarding system life cycle phase models, but is a cornerstone for performing value streams efficiently (Scheithauer 2012). For satisfying the just-in-time principle, Ohno has defined the objective to minimize the throughput time between taking an order and delivering the product item built to that particular order to the customer. Originally, this definition has been established in the scope of manufacturing considering the time needed for manufacturing plus the time needed for delivery. Later works on lean consider also product development (Morgan and Liker 2006).

The definition of throughput time as the time between order intake and delivery fits well into the systems engineering heritage: A customer provides requirements, a contract is negotiated, and then the system is developed, manufactured and delivered to the customer by the supplier. The general issue with this model is concerned with the quality of the contract. There is ample evidence that systems engineering endeavors may frequently lead to product capability underachievement, unplanned cost increases, and massive program delays. Of course, improving systems engineering competencies and project execution processes in the supplier organization is always a good idea to remain efficient and competitive. But all this may not be sufficient to cope with the initial risks induced by the quality of the contract itself.

One of the standard excuses of systems engineers experienced again and again is that the time for the necessary systems engineering activities before contract signature would have been too short. Such complaints may state a simple truth: The time period between receiving a demand from a customer and the customer wanting to sign a contract is actually too short to generate sustainable systems engineering solutions. Therefore, it is recommendable to find another approach to solve the problem of contract quality.

Just-In-Time from a Customer Perspective. Marketing theory offers a better model of customer behavior before a customer is stating a solid demand compared to systems engineering. In systems engineering, the terms stakeholder needs and stakeholder requirements were traditionally almost taken as synonyms (Haskins 2011). This is currently changing, but the move is not completed yet (ISO 2011). Marketing terminology uses a distinction between needs, wants, and demand (Kottler and Keller 2012). The marketing terminology fits well to the motivation cycles investigated in psychology outlined in the next paragraph (Achtziger and Gollwitzer 2010).

People have a number of needs. They are conscious about some needs, about others they are unconscious. Satisfying all needs simultaneously is impossible. Thus, people have to make a selection which need should be satisfied actually. By this, a need becomes a want. However, there may be not the right occasion to satisfy the want immediately, may be due to waiting for a better opportunity, due to missing products featuring the wanted capabilities, or due to current unaffordability. In the want state, people invest personal effort by browsing related information and making contact to potential suppliers or distributors. Waiting for a good opportunity, the will to spend their money by corresponding purchases is present in order to satisfy the need. Actual demand is established when people start to achieve a contractual agreement with a potential supplier. At this point in time, people usually become also rather impatient regarding the time by which a deal can be committed and the time by which the product is delivered.

For the supplier, it is recommendable to gain more time for preparing high quality contracts for complex and innovative products than to wait until the demand has become evident. Consequently, the systems engineering activities have to start earlier in the motivation cycle. But a need may not develop into a want, and a want may not lead to an actual demand. A good compromise would be not to invest too much when a new need is identified, but to react more proactively when a need is transitioning to a want. The solution elaborated below focusses on increasing the lead time before contractual commitments are made and on maintaining economic efficiency together.

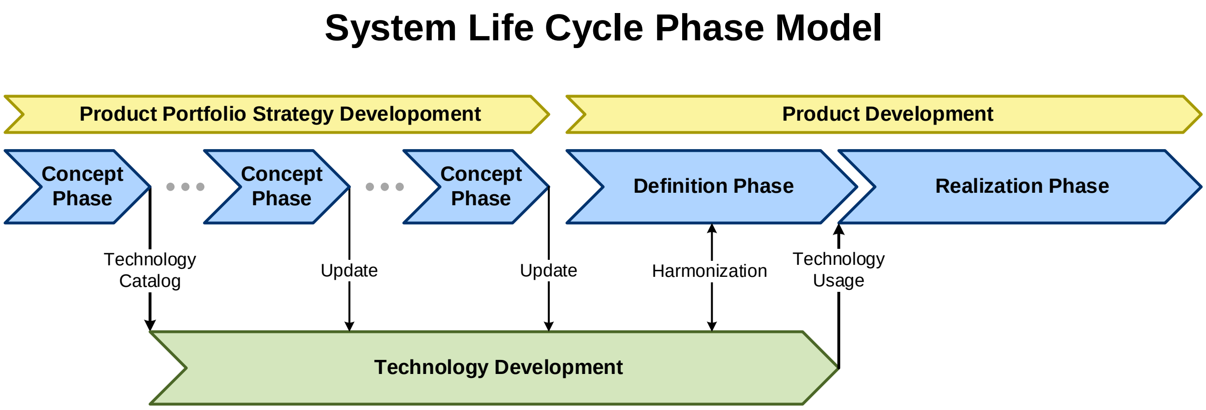

Figure 1. System Life Cycle Phase Model

Product Portfolio Strategy Development and Product Development. Figure 1 shows the life cycle phase model that has been derived on the considerations above. On the top of the figure, a distinction is introduced between product portfolio strategy development and product development. Product portfolio strategy development acts on needs. The goal is to have a portfolio of current and future products that provides rich opportunities for reacting on developing customer wants in order to satisfy later customer demand successfully within short time scales. Not all yet non-existing elements in the product portfolio are likely to become successful products in the end. Some will never materialize. Others may be less successful as envisioned. But some may become the cash cows of the future. For this reason, it is recommendable to perform the product portfolio strategy development with minimum investments. Another reason is the networking capital bound by these early stage activities. As the time periods before the breakeven point on the return-on-investment is achieved are comparable long, every enterprise tends to keep budgets for the product portfolio strategy development low. However, in either extreme case, e.g. over-investments or no investments into the development of the product portfolio strategy, an enterprise's future is jeopardized.

Matters change when the prospects to progress an element of the product portfolio strategy to a successful product becomes evident by clear signs of customer wants. Half-hearted investments may let a business opportunity pass by without generating possible profit. That means decisions on whether needs are turned into wants are necessary by the enterprise to invest in product development significantly.

Below the stages product portfolio strategy development and product development, the system life cycle phases concerned with those stages are drawn. The concept phase is aligned with product portfolio strategy development. Product development comprises the definition phase and the realization phase. Technology development shown at the bottom of Figure 1 is not a part of the system life cycle, but runs in parallel to iterations of the concept phase and the definition phase. The three system life cycle phases concerned with development, and technology development are described below in more detail.

Concept Phase. The concept phase is concerned with identifying current and future customer needs. The context has to be investigated in which a product should provide its benefits to the customers, users and any other stakeholders who will be concerned with the product in the utilization phase. This will lead to an understanding of the system environment including its functions and internal structure. Operational requirements are derived for the intended product in order to provide customers and their associated stakeholders with new or improved beneficial capabilities. Alternative product solutions are investigated, and evaluated regarding how effectively they can serve the intended missions. Following an overall life cycle approach, all consecutive life cycle phases and the additional needs of all other stakeholders concerned with the system somewhere along the system life cycle have to be considered.

Another strand of activities is concerned with the question, how the possible product solution alternatives may become reality. At this point, the task tends to be challenging for the systems engineers. Recording well known problem solutions would consume a lot of resources without really paying off in this phase. Those solutions can be easily re-iterated during product development. The major tasks are to put the best endeavor to identify new problems not having been aware of before, and to develop principle solutions for known problems for which no solution exist yet. At this point, the knowledge, the experience, and the innovative ideas present in the enterprise are important. Activities distributed over the whole systems engineering value stream are performed selectively as appropriate. The results are: First, technology catalogs listing all the technologies needed for the product, the current technology readiness for the intended application, and a forecast how the technology readiness may develop in the future. Second, a projection of the system life cycle costs based on parametric cost estimation and known system life cycle costs of existing system elements. Third, a register of all technical and non-technical risks that could hamper the development turning the system concept into reality has to be established and maintained.

Following this process, more and more solution alternatives are discarded with the maturation of the system concepts. In parallel to needs becoming wants, it can take years from the initial identification of needs to a mature product concept that is ready for being transferred to the product development stage. Continuous funding for the concept phase may be not affordable, and may also be not the most efficient way forward due to human behavior in reaction of interrupted tasks (Lewin 2012). For this reason, it may be better to assume a number of discontinuous concept phase iterations. The definition of system concept maturity levels is an idea not further followed up here. But it may be a good idea for monitoring and assessing all the elements in a planned product portfolio based on such a rating. Full maturity of a product concept is achieved when the number of new problems regressively achieve a low identification rate, and when promising principle solutions for all known problems are outlined.

Definition Phase. In the definition phase, the overall systems engineering value stream is executed from the design of the overall system to the design of all abstract system elements. Different from the design activities of the concept phase, systems engineers now have to strive for completeness of the design. Based on existing or improved design solutions, and the results of specific technology development activities, a product solution in terms of system requirements, functions and architecture is developed for satisfying the stakeholder needs on the overall system in an effective and efficient way. Effectiveness here is meant in the sense of achieving a design that satisfies the stakeholder needs and that can be implemented successfully. Efficiency is meant in the sense of an optimum solution regarding system life cycle costs considering also time scales.

To a wide extent, the knowledge of the product design allows to perform product life cycle cost estimation following a bottom-up approach. Compared to the parametric, mainly top-down cost estimation techniques applied in the concept phase, the resulting figures generally should be more realistic. A reliable projection of the system life cycle costs is a prerequisite to minimize the enterprise risks. For this reason, the definition phase should be completed before development and delivery contracts with customers and suppliers are agreed and signed.

Consequently, the definition phase has to be performed under the regime of the just-in-time principle. Implementing the just-in-time principle means to enable and manage the value flow. Of course, enabling and managing the value flow is always a good idea. But for an enterprise developing and marketing innovative products, superior value flow management capabilities in the definition phase are a crucial success factor due to the huge amount of interrelated uncertainties. How this may be accomplished is described in a previous paper (Scheithauer 2012). In systems engineering, value is represented by established configuration baselines and released versions of work products containing information that is required by downstream processes as a point of reference. Properly managed concurrent engineering for reducing waiting and for avoiding the careless induction of design inconsistencies are the main elements for improving the value flow in systems engineering. Value stream centered concurrent engineering is applied to the different system elements of the system architecture, and to iterations performed in parallel across the system architecture and for individual system elements.

In practice, progress in this direction is many times jeopardized by a divide-and-conquer mode of operation extending the usage of work breakdown structures far beyond effort estimation. As a side note, difficulties for overcoming the reluctance to adopt model based systems engineering in practice seems to have the same root cause. Thus, the progression of value flow management capabilities may gain more urgency in the further evolution of systems engineering. The author is confident that what high-qualified craftsmen achieved in manufacturing will be also achieved by high-qualified systems engineers in development eventually.

Realization Phase. In the realization phase the focus lies on system implementation and system integration. However, the quality of the design of the overall and all abstract systems will not be perfect at the end of the definition phase. Suppliers may generate knowledge challenging the system architecture. And, continuing work on the overall system and abstract systems may also lead to an improved understanding of stakeholder needs. In consequence, nearly all parts of the overall systems engineering value stream may be iteratively performed again. As in the definition phase, value flow oriented concurrent engineering remains an important success factor to cope with iterations due to lessons learned, especially as deeper supply chains are fragmented.

While repetition of systems engineering activities of the definition phase in the realization phase are the usual case, challenges to the understanding of the product's system environment and the envisioned mission effectiveness may have a wider adverse impact. In this case, the product portfolio strategy is undermined. The expected revenues may not be achievable. The profitability of the product may become questionable. Other investments into the product for marketing or preparation of production taken in parallel to product development may increase the damage to the enterprise. Furthermore, the reputation of the company may suffer with unforeseeable future adverse impacts.

The outcome of the realization phase is the implemented product. The criteria to be fulfilled vary according to the business model applied for the product. In infrastructure engineering, this may be achieved by handing over a one-off product to the customer, or by installing a first product item that is afterwards deployed multiple times. In low volume production, the product may be ready for production, if also the manufacturing line is ready. Or, in mass production, a further productionization phase may follow preparing globally distributed production with the need to consider local supply chains.

Technology Development. There are three reasons for segregating technology development from product development. First, technology development may demand investments that exceed the budgets an enterprise may be willing to spend for product portfolio strategy development. Second, technology development is a burden for the definition phase because it jeopardizes improvements regarding the just-in-time principle (GAO 1999). Third, the huge investments necessary to progress technology should be better justified by using the new technology for more than just one element of the product portfolio as a matter of reducing enterprise risk.

For the purpose of the business planning process defined below, technology development is broken down further into three stages: (1) management of innovative ideas, (2) technology roadmap planning, and (3) technology project execution. The first two stages belong to the business planning process, and will be further considered below. Technology project execution needs to be reflected in the business plan due to the considerable huge budgets to be spent usually. Technology project execution should be governed following the well-established technology readiness levels (Mankins 1995). However, the criteria for assessing technology readiness levels depend on the application of the technology in a particular product. For example, a particular technology may have actually reached a higher technology readiness level when applied for a mission-critical function in one product than for a safety-critical function in another. The technology readiness criteria applied for governing the technology project execution itself have to take this into account.

Business Planning

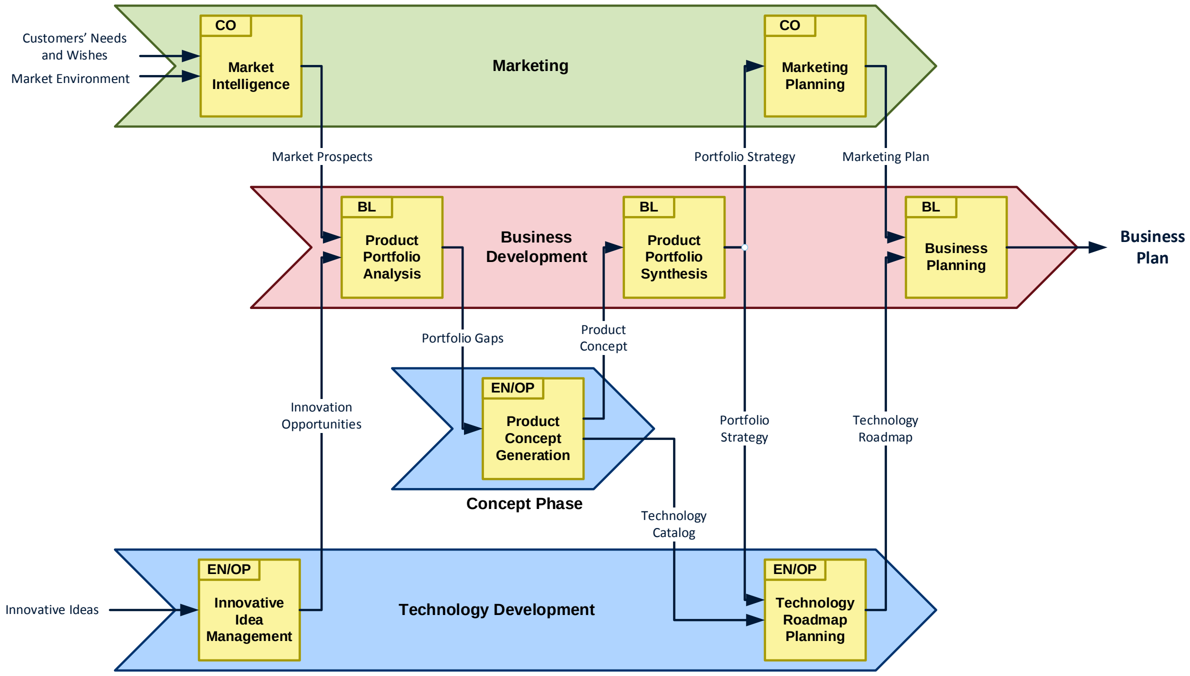

Figure 2. Business Planning Cycle

Integrated Business Planning. The term integrated business planning has been coined mainly by large accounting firms (Capgemini 2011; PWC 2012). The point of view on an enterprise is the financial dimension. Integrated business planning aims to get better visibility on the financial projection of an enterprise considering the environment it is operating in and the activities the enterprise is performing. Improvements are targeting for increasing the profit, improved risk management, and higher flexibility of directing the enterprise's future.

The business planning process defined below and illustrated in Figure 2 is a solution element to make progress in the direction of the objectives driving integrated business planning. It shows especially the importance of systems engineering for integrated business planning.

Holistic Marketing. Holistic marketing is another approach to tie all aspects of an enterprise together in order to govern the operation of an enterprise (Kotler and Keller 2012). Of course, this time from a marketing perspective. Kotler and Keller define the following core business processes as the value chain: (1) market-sensing process, (2) new-offering realization process, (3) customer acquisition process, (4) customer relationship management process, and (5) fulfilment management process. The overlap with systems engineering is evident. The new-offering realization process refers in total to engineering and production. With the stakeholder requirements definition process, systems engineering provides a method beneficial for activities in the market-sensing and customer acquisition processes.

It is not the goal of this paper to segregate marketing and systems engineering properly, or to do the same for integrated business planning and systems engineering. The combination of market demands, innovative and efficient products, and healthy enterprises are the pre-requisites for a sustainable success of a mature economy. Sustainable success in any of the three dimensions is dependent on sustainable success in the two other dimensions. In the short term, preference of any dimension may increase the success with respect to this dimension. But in the long-term only a balanced score in all three dimensions will pay off. The business planning process illustrated in Figure 2 tries to integrate the three dimensions for providing an integrated view on business planning. The following paragraphs describe all the activities shown in Figure 2.

Market Intelligence. Market intelligence is concerned with the identification of current and future needs of customers and further stakeholder groups who would be involved in product utilization. In depth knowledge of the product application domains as well as of stakeholder views and habits are necessary pre-conditions for successful market intelligence. The stakeholder requirements definition process provides the methods and tools to record stakeholder requirements derived from the identified needs. The outcome of the market intelligence activities are future market prospects.

In the market intelligence stage, an enterprise should avoid to make any promises or commitments to potential customers because this may accelerate the customer's motivation cycle and the need will become a want too early. If not already a mature product concept exists, the lead time for developing mature product concepts and agreeing sound commitments may be too short to achieve contractual agreements of high quality.

Innovative Idea Management. The future oriented competencies and capabilities of an enterprise are not at least dependent on the innovative ideas generated or adopted by the members of the enterprise. The innovative ideas may be categorized as follows: (1) ideas for new products, (2) technological ideas enabling the invention of new products, and (3) innovative ideas increasing the efficiency of product solutions.

In the first case, the enterprise has the chance to act as a real innovator being the first on the market, owning the important intellectual property rights, and keeping competitors on distance. But there are a number of risks to cope with, including the feasibility of the product, and a realistic forecast of time scales and of quantities of the future demand. In the second case, technological ideas may have no direct use for any product concept. However, it is important to retain those ideas in order to avoid the need for re-inventing them when searching for technical solutions for new products in the future. In the third case, either capability enhancements or life cycle cost reductions may result. Capability enhancements may extend the life cycle of products by generating new variants, and may generate additional demand. Especially, life cycle cost reductions may make products affordable to additional customer groups.

Product Portfolio Analysis. Based on the market prospects, an analysis of the product portfolio investigates whether (1) current products in the portfolio can satisfy the needs, (2) new product ideas may find their customers in future, (3) capability enhancements of existing products find their business case, (4) improved product efficiency would open the market to new customer groups, or (5) new products need to be invented according to the business strategy of the enterprise. Depending on the outcome, the demand for creating new product concepts, altering existing product concepts, or maturing existing product concepts further may arise.

Product Concept Generation. The product concept generation follows the concept phase description stated above.

Product Portfolio Synthesis. Considering the product concepts and their maturity, the product portfolio strategy is updated. The maturity of each element in the product portfolio is rated. For planned product elements, the envisioned entry into service dates are defined. Priorities are allocated to all the elements of the product portfolio.

Marketing Planning. With the updated product portfolio strategy, marketing plans can be established or re-iterated. Quantitative forecasts for future sales are the outcome. Probability ratings are included for individual products and markets assisting in setting priorities.

Technology Roadmap Planning. In parallel to market planning, technology roadmaps are established. Inputs for technology roadmap planning are the product portfolio strategy and the technology catalogs associated to all the elements of the product portfolio. Technology development projects are defined and planned. Preferably, a particular technology development project should be of benefit for several elements of the product portfolio.

For each technology project, criteria are defined to be satisfied for fulfilling the technology readiness levels with respect to the designated projects. However, this may be a cumbersome process. With every iteration of performing the business planning process, product concepts may be updated and the corresponding technology catalogs may be altered. For this reason, it may be more reasonable to define the technology project milestone criteria somewhat independent from the technology readiness level criteria applicable to each product the technology is designated to. To ensure that technology projects do not deviate from what is required by the corresponding products, running technology development projects need to be reviewed regarding the fulfilment criteria for passing project milestones and for progressing through technology readiness levels.

Business Plan Compilation. With the information from the marketing plans and the technology roadmap planning, now decisions can be made for which purposes the enterprise’s budgets shall be spent. This includes (1) financing marketing and sales campaigns, (2) investments into technology development projects, and (3) budgets for product development, manufacturing, and product delivery and support.

The business planning process is performed iteratively. For markets with long product life cycles, one iteration per year may be sufficient. But for fast developing and changing markets a higher iteration rate with several iterations per year will be beneficial. That does not necessarily mean that all activities run with the same iteration rate. For production related planning activities on volatile markets, short term adjustments may be necessary while the development of the product portfolio strategy runs at a slower pace.

Conclusions

This paper proposes an integrated business planning process showing the interaction of marketing, the management of innovative ideas and systems engineering. Systems engineering is supportive to market intelligence activities by providing the stakeholder requirements definition process, but the most important contribution is the generation of system concepts in support of the development of a product portfolio strategy. Regarding technology development, the management of innovative ideas and technology roadmap planning are the activities supporting the integrated business planning. In the flow of thoughts the following findings stand out:

First, system life cycle models should be either categorized as system life cycle phase models or value stream representations. Both should be defined in a complementary way with value stream representations as the basis for managing the engineering projects internally, and life cycle phase models for supporting the organizational management, customer and certification authority communities. The same parts of the systems engineering value streams may be executed in different life cycle phases, but their purpose and the way they are performed may differ.

Second, systems engineers should widen their understanding of stakeholder needs and stakeholder requirements in the direction of marketing terminology including needs, wants, and demand. Here marketing makes a better use of psychological knowledge on the human motivation cycle.

Third, the just-in-time principle is applicable in systems engineering also as the time span between recognizing needs becoming wants, and making contractual agreements with customers and suppliers. Reducing the throughput time is constraint by ensuring that the content of contracts feature a high quality.

Fourth, for the product portfolio strategy development the investments should be minimized. Systems engineers should therefore avoid to completely define the product solution, but to concentrate on understanding the product's environment, product solutions fulfilling the intended missions effectively, and on the identification of unknown problem and generation of principle solutions for known problems for which no solutions exist yet.

Fifth, the holistic view of systems engineering is paralleled by other viewpoints, e.g. integrated business planning and holistic marketing. But none of these views alone is sufficient to capture the reality of an enterprise comprehensively. Tying them together in the business planning process is the route for improving the operation of the enterprise.

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Biography

Dieter Scheithauer studied electrical engineering with special emphasis on automatic control at the Universität der Bundeswehr München resulting in the degree of a Diplom-Ingenieur univ. in 1980 and a doctor’s degree (Dr.-Ing.) in 1987. His service as Technical Officer in the German Air Force ended in 1988. From 1988 to 1999 he was employed by Industrieanlagenbetriebsgesellschaft GmbH (IABG). He worked in a branch mainly delivering technical expertise to the German Ministry of Defence and other government organizations. Throughout his professional career he contributed in various roles to the flight control system development for major European military aircraft and helicopter programs. Furthermore, he acted as project manager for unconventional airborne and ground-based systems. In 1999 he joined the Airbus Group. Since then he has worked mainly in the field of process engineering. He now holds a position as Senior Expert Systems Engineering Processes within the division Airbus Defence and Space. Convinced of the importance of systems engineering for the company, he contributed to achieve its high level of recognition by the Airbus Group today.
He is a former president and an honorable member of GfSE e.V. – The German Chapter of INCOSE. He represents Airbus Defence and Space on the INCOSE Corporate Advisory Board. And, he is an INCOSE ESEP.