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DEVELOPING LIFE CYCLE ORIENTED INNOVATIONS WITHIN THE TURBULENT BUSINESS ENVIRONMENT

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ABSTRACT

Generating successful innovations is a key factor for companies to survive within today's business environment in the long term. When developing new products and processes the integrated perspective on their whole life cycle gets increasingly important nowadays for various reasons. The last couple of years showed several examples of innovations that did not enfold their full potential or did not even work at all. However, these failures can not really be explained through previous innovation research. Therefore, the Life Cycle Innovation framework is proposed in this paper which shall integrate and extend previous approaches in a holistic description model. Different life cycle phases are practically represented by different actors within an extended supply chain network – this system is identified as most relevant for a successful development of innovations. Whereas the network is additionally strongly influenced by external factors, each one of the involved actors has specific requirements regarding all innovations within the system. To avoid unforeseen failures and tap the full potential of innovations all of these requirements urgently have to be considered as early as possible in the innovation process. Idealistically this could lead to different effects potentially resulting in more and better innovations with less resource input. To validate the ideas of the framework and to derive recommendations regarding system design and optimal strategies the theoretical description framework was transferred in a simulation approach in the next step. Based on this model first simulation experiments were also conducted.

Keywords: innovation, extended supply chain, life cycle innovation model

1 INTRODUCTION

Today's business environment is strongly affected by decreasing time to market and shorter product life cycles as well as rising product variant diversity through integration of specific customer demand, increasing production volume fluctuations and rapidly changing technologies. Within this dynamic environment, the efficient generation of promising innovations is a critical factor for a company's survival and success on the market. Studies show that by 2007, the sales of new products introduced in the three preceding years are expected to generate 35 percent of total revenue, a huge increase from 21 percent in 1998 [1]. Additionally, companies across industries are shortening the time to market for new products from an average of more than 18 month in 2001 to less than 13 month in 2007. In consequence, by 2010, products representing more than 70 percent of today's sale will have reached the end of their life cycle on average [1].
Due to growing dynamics of the innovation processes the number of interrelated and interdependent business processes in extended supply chain networks increases. Moreover the ongoing internationalization and the quickly rising amount of product- and process-related innovation information that must be exchanged within innovation processes also result in a significant increase in complexity [2].

Besides these complex and dynamic circumstances within the business environment, all innovations naturally have their own specific life cycle. Ecologically driven regulations as well as the increasing importance of life cycle costs lead to a stronger need for a holistic consideration of all product life cycle phases. Exemplarily speaking of product innovations, the new product firstly have to be developed and produced before distributing it to its users. After reaching the end of its usage phase, end-of-life aspects like disposal or recycling get important.

Specific characteristics of innovations can have effects in all of these phases, so their specific requirements necessarily have to be considered. Within a life cycle management framework, innovation processes naturally stand for the very beginning of a product's life cycle and can be classified as part of the product management (Figure 1) [3]. With respect to superior values like sustainable development on a normative level, innovations idealistically emerge through the conscious search within chosen fields which are defined through the life cycle strategy process. Life cycle design as the rather operational level stands for the further development of filtered innovative ideas. [4] In this phase the fundamental properties of an innovation and relevant costs that actually emerge in later stages of the life cycle are determined. Conducting design-for-x-options within the development processes have positive effects for the production (Design for Assembly, reduction of production costs) or use/ maintenance of a product (Design for Service) for example. Additionally environmental driven regulations like WEEE (Waste Electrical and Electronic Equipment), RoHS (Restriction of the use of certain hazardous substances in electrical and electronic equipment) or ELV (end-of-life vehicle) lead to extended product responsibilities for companies and force them to respect these end-of-life aspects when developing new products or processes. Re-x options like re-use or remanufacturing also offer economic advantages and opportunities to save costs or achieve additional revenues.

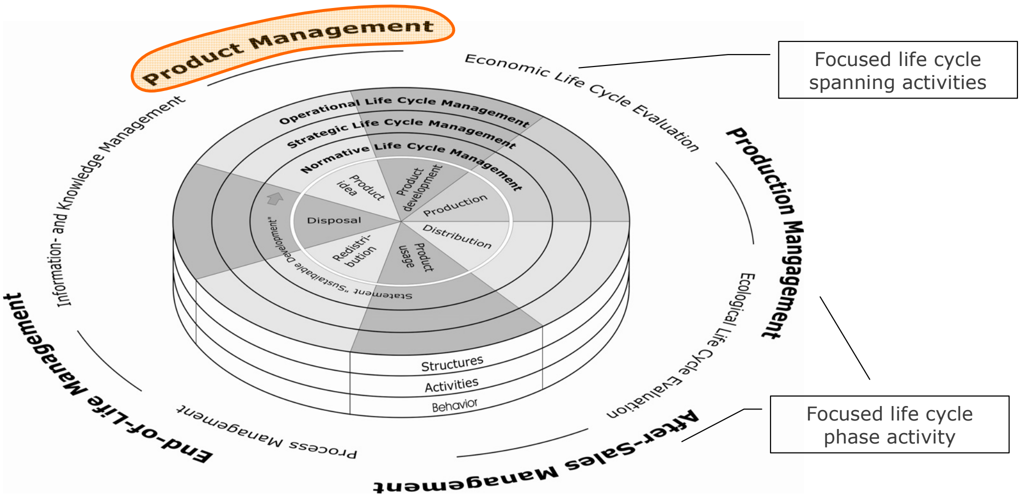

Figure 1. Braunschweig Framework of Life Cycle Management

Life cycle oriented innovation management overcomes an isolated perspective on single life cycle phases and pursuits the conscious consideration of all life cycle phases with an optimization over all stages. Since various actors can be involved during the whole life cycle, this naturally includes cooperation and coordination processes between all these players. In the following the term life cycle innovation is used for this kind of innovations with this integrated perspective.

2 THEORETICAL BACKGROUND

The term innovation can be defined and specified in different ways [5] [6]. Important and common distinctions are made between incremental and fundamental innovations, product- (good or service) and process-innovations or technological and organizational innovations. However, the basic requirement for an innovation is that the product or process "must be new (or significantly improved)" [6] compared to the former state.

Innovations can be analyzed on different aggregation/ abstraction layers. Originally starting from economic driven research of innovations within a nation, companies as a major source of innovations were also analyzed from many authors. Over the last years, bi- or multilateral co-operations have become an important strategy for companies to cope with the increasing requirements of the dynamic and complex environment. Due to its specialty, the cooperation or network layer was identified as the third major perspective lying between the national and company layer. As depicted in Figure 2, two major levels of research additionally can be differed independent from the focused layer. The first

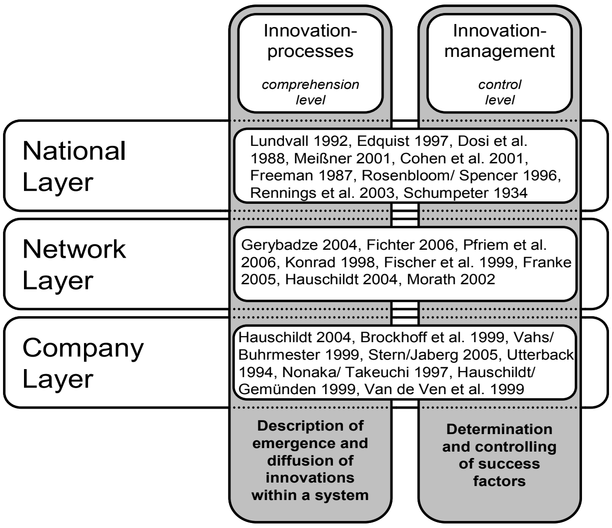

Figure 2. Classification of innovation research

level strives to get comprehension of the actual emergence (triggers etc.) and diffusion of innovations within the system (national level, network, single company). Results are approaches that describe system behavior regarding innovations like causal diagrams, phase models or the funnel model. Understanding innovation behavior is naturally a basic requirement for its strategic or even operational management conducted by politicians (national layer), company executives or network managers. As innovations are strongly influenced by diverse factors, these factors crucially need to be identified and consciously formed to support the innovation process. Innovation management provides the framework that enables and may improve the efficiency of innovation processes.

In the following, the three layers of innovations and their basic ideas are shortly presented to gain overview about recent literature and to derive research gaps.

2.1 Innovations in a national context

The determinants of technical progress as well as the diffusion of innovations in national economies and its effects on welfare and economic wealth were always important topics in research of classical economics [7]. From a national perspective, innovations are the result of complex interactions between different players. To explain these various complex interdependencies of several actors, the concept of "National Systems of Innovation" (NSI) was introduced at the beginning of the 1990s. According to that concept, a country's innovation system is based on a complex network with actors that offer (develop) technology (e.g. universities, research institutes) and others which demand and use it (e.g. companies). These actors are imbedded within the influencing framework, which includes aspects like the basic educational system, political decisions regarding R&D and innovations, legislative settings (e.g. patent law, taxation), financial and communicational infrastructures, industry structures (e.g. competition, market accessibility), international relations or the general social, and economic situation of a country [8] [9] [10] [11] [12] [13]. Studies also focus on the variables that actually determine the innovation climate (restraining and supporting factors) in countries and the innovation behavior of companies within an economy. Due to the importance for innovative behavior on a national level, environmental protection and political decisions are specifically addressed by several authors [14] [15].

2.2 Innovations from a company level perspective

As stated above, national policy and regulations are major triggers for the creation of innovations within companies. In addition, research identified other variables like market and society expectations, technology advancement in general, the company's own vision and values, or other internal characteristics which can strongly influence sustainability oriented innovative behavior [2].

The innovation process itself involves several departments within a company and is often described as a linear process with successive phases called the "innovation pipeline" [16] [17]. However, traditional linear phase models of the innovation process are often idealized theoretical approaches;

they do not consider a realistic framework (phases are not necessarily successive), interactions of different phases (e.g. feedback loops) or interactions with other actors. Over the years, in an evolutionary process the innovation process models were more and more developed to rather interactive approaches, which shall integrate these realistic settings [18]. The so called “fireworks”-model can be seen as the latest stage of this evolution process and is based on long-term empirical studies [19]. Although there is no basic, generally accepted process model, one generic approach can be derived which is applicable for all products (goods and services) and business organizations: it always begins with the creation of ideas, their evaluation and finally the realization and use of accepted concepts [20]. Independent from the underlying process, in the end, just a few of the original amount of ideas are actually realized due to permanent evaluation with technical and economical criteria - even less are successful on the market. This process is described by the so called funnel model [21]. Besides the innovation process itself, another focus in literature lies on the management of innovations within a company which is based on some major determinants. They can be divided in hard or structural factors like the innovation strategy (e.g. product versus process innovation, innovator versus adopter) or the defined organizational structures and processes [16] [22]. Soft factors like leadership, corporate culture, human resources in general, experiences with prior innovations, or informal communication are less directly controllable but have important influence on idea generation and knowledge transfers within a company [5] [23]. Research considers innovation promoters as individuals who support and potentially enforce innovations within an organization as one of the most important factors for success in the management of innovations [24].

2.3 Innovations in cooperations and networks

To improve the innovation process and share costs and risks, cooperation on different levels is a common way for companies to meet the strong need for innovations in the marketplace [26]. Studies underline that collaboration is stronger in dynamic environments and also worth the effort because it has positive effects on innovational success [5]. Cooperations are possible between businesses with similar needs and problems in different or even the same branches (which could also include direct competitors) or within a supply chain. Whereas temporary bilateral activities are common for several years, multilateral network structures become more and more relevant nowadays [5] [27] [28] [29]. Examples for that are concepts which are based on geographical closeness of the actors like regional technological cluster of companies (e.g. Silicon Valley) [30]. “Innovation networks” allow the optimization of the acquisition and realization of innovations by the sharing of information and knowledge [26]. By using innovation networks, companies virtually increase their R&D capabilities and derive benefits from faster identification and evaluation of ideas and prototypes as well as from increasing probabilities of innovation success.

Research identifies some key factors that strongly influence the success of all network based concepts. Examples are the complementarily and compatibility of partners (regarding their visions, goals, expectations, innovations or cooperation cultures), the capability of communication and transfer structures, and the efficiency of the network management [27] [25] [31]. As stated above, individuals namely so called promoters, are key players to enforce innovations on the company layer. This is also true for the network layer: recent research enhanced the approach for networks with the introduction of the “extended promoter model” which includes interactions of promoters from different actors (e.g. companies) within so called “innovation communities” [27]. Whereas the existence of such communities and potential advantages are theoretically described in research, their actual effect was not sufficiently analyzed through studies yet.

3 DESCRIPTION FRAMEWORK FOR LIFE CYCLE INNOVATIONS

3.1 Problem Definition

As a result of the dynamics within the business environment the fast development of successful innovations has even more become an essential factor for the company´s survival on the market. However the last couple of years showed many examples of product or process innovations within diverse branches which did not really work as intended. Despite of actual good underlying ideas, many innovations fail on different phases of their specific life cycle. Reviewing literature it gets clear that there is no theoretical approach existing which can really explain all these failures. Various approaches trying to explain the emergence, diffusion and management of innovations on different levels can certainly be found. However, life cycle innovations which explicitly consider various influences within different phases can not really be integrated in previous approaches due to various reasons:

- National and company perspective are treated relatively isolated. However this strict distinction is not necessarily given in reality where complex and very dynamic interdependencies between the different layers and actors of the business environment naturally exist - innovations are always productive interactions of internal and external factors [32]. Additionally, there are actual influences which even go beyond the actors of the NSI (e.g. world market prices for materials).
- Previous approaches lack of the integration of the extended supply chain. However, this system has necessarily to be taken into account to include end-of-life aspects like redistribution, disposal or recycling and respect relevant aspects for innovations like new ecologically driven directives (e.g. WEEE, ELV, RoHS).
- Multilateral networks are common in today's turbulent business environment whereas corresponding research is still lacking in this point compared to detailed work in other fields. This is notably true for vertical concerted activities which are crucial for the success of an innovation: after all, it is the whole supply chain network, which can be influenced by an innovation and vice versa and so it is necessary to include all involved actors and their requirements to avoid unforeseen failures.
- Linear phase models of the innovation process are also still common, but interactive approaches should be state-of-the-art, because external influences, interactions, feedback loops et cetera are existing in reality.
- There exists no consistent and generally accepted innovation model. Models differ from each other and interdependencies between different innovation phases are often not or not sufficiently integrated. The compatibility to different types of innovations or branches (e.g. service, goods) is not necessarily given.
- Additionally, these models are often just qualitative descriptions that often do not really help to understand the dynamics within the actual working innovation system.

Increasing complexity through various external legal, political, social, and customer requirements and the integration of a growing number of actors into an innovation's life-cycle requires a turning away from innovation models that focus only on individual actors and single life-cycle phases. In fact, an integrated life-cycle oriented model of the extended supply chain network and its innovation processes working in and covering all product life phases and actors of an innovation seems to be a promising approach.

3.2 Developing a description framework

As stated above, understanding the system behaviour regarding innovations is an essential requirement for a conscious management process. While not considering the idea of life cycle innovations prior description models can not support innovation management within extended supply chain networks. An integrated framework which reflects these realistic circumstances is missing. Therefore a Life Cycle Innovation Framework is proposed which integrates both theoretical work through literature review and findings from various case studies in a holistic description approach.

After defining system borders, considering the basic structure of the system is the next logical step of a systematic view because it naturally strongly influences system behaviour in the end. The focus of the Life Cycle Innovation Framework lies on extended supply chain networks [33]. To include end of life aspects like conducting re-x options with reverse logistics to close material flows this extension of the conventional supply chain is indispensable. Actors within the extended supply chain are strongly interconnected and depending on each other. Speaking of production processes and material flows the actors of the extended supply chain network are naturally physically connected. Since innovation is a part of the product management the informational connections through information flow between companies within the system are even more important in this case. Additionally, the whole system is influenced by diverse external factors like legislation, culture, education system, competition, world market prices etc. Figure 3 depicts the structure and system borders of the Life Cycle Innovation Framework with its integrated consideration of all actors' innovation processes through information flow under the influence of various external factors.

Referring to innovation research each individual actor of the network has its own internal innovation process which can be described through diverse approaches. Abstracting these models to a generic approach, an innovation is always the result of an internal process with three phases including the creation, evaluation and realisation of ideas. Filter effects during this process are depicted by the "innovation funnel" model. As practical examples show, concentrating on this intern oriented perspective can lead to unexpected and expensive failures of innovations in different life cycle phases. This means that the innovation at least does not have the full intended effect or could not even work at all due to unforeseen problems in different stages of their life.

To solve this problem basic ideas of the traditional innovation management have to be adapted for the whole extended supply chain. Life cycle innovations need an extended and externalized perspective of this process explicitly including all relevant phases and different actors of an innovation's life cycle. Successfully going through the innovation funnel of a single company is just a necessary but not a sufficient condition: to be able to successfully create, implement and enforce innovations within the complex business environment of an extended supply chain network, all other affected actors must be integrated in each phase of the innovation process, too. As a result of external influences as well as internal parameters, each actor has specific requirements regarding every innovation within the system. To enable the implementation and to tap the full potential of innovative products and processes within the network, all these requirements need to be considered holistically and matched through all phases of the life cycle. Idealistically this should take place as early as possible because life cycle costs are mainly determined and can actively influenced in the design / development phase within the product management whereas they actual occur in later life cycle stages.

Practically the coordination process on the network layer is conducted by individuals as representatives of the relevant actors which also transfer the results back to their companies. This directly addresses the extended promoter model as described above with its interactions within innovation communities.

3.3 Effects and potentials within the Life Cycle Innovation Framework

The idea of the Life Cycle Innovation stresses the importance of an early integration of all life cycle requirements in every phase of the innovation process to foster the success of new products or processes. Realistically, every life cycle includes different players within an extended supply chain network. Due to concerted activities on the network layer, the innovation performance of every involved company can be significantly optimized. Viewed from an idealized company perspective each actor can potentially generate and implement more and better innovations in less time and with

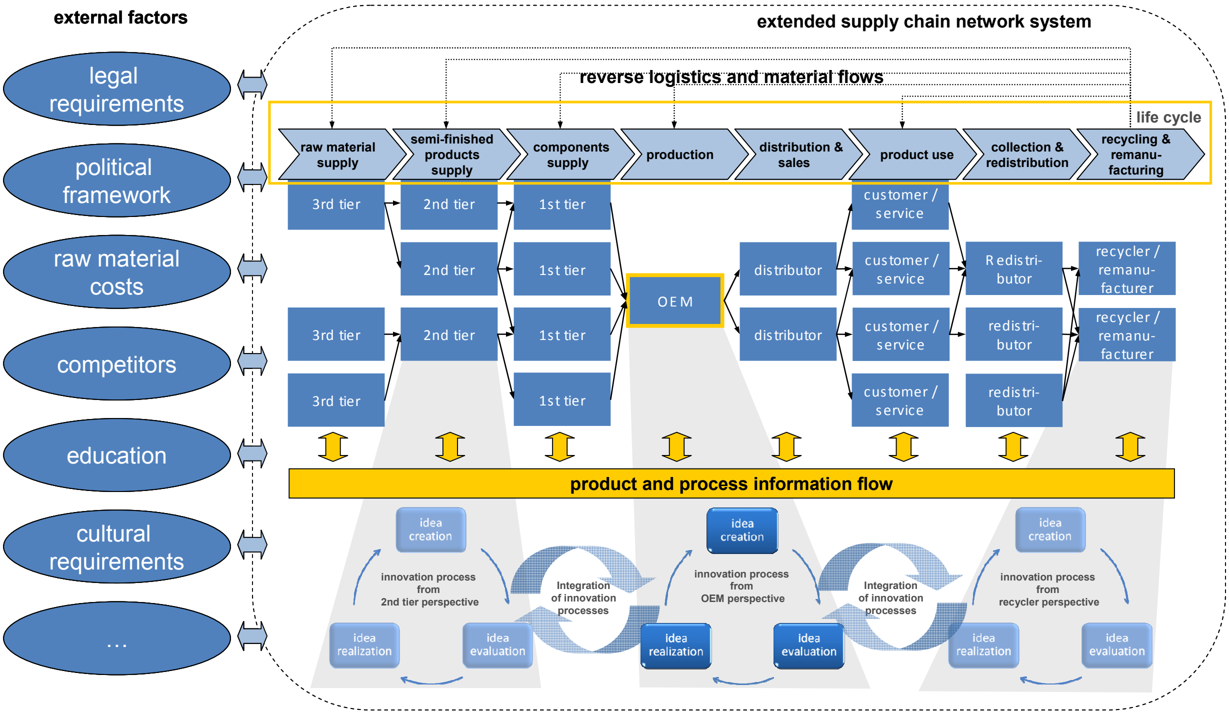

Figure 3. Life Cycle Innovation Description Framework

less resource input (less costs). This literally means an increase of the innovation productivity as this is the quotient of output to input. The different effects resulting from an integrated innovation approach can be theoretically described and depicted with the established funnel model of the innovation process on the company layer (see Figure 4, the original form of the funnel is shown in rectangle area 1).

3.3.1 Idea creation

Concerted activities of relevant actors within of the extended supply chain network can potentially result in more and also better ideas per company for two major reasons. Firstly, through information exchange respectively knowledge transfer within the innovation community innovation diffusion is fostered. Each promoter could get new ideas from other partners and could simply adopt them in his own company. Discussion about current problems etc. can lead to the generation of totally new ideas on the network level. Typical triggers for this emergence within the community are the conscious perception of similar problems of different actors, potential network effects or economies of scale / scope.

From a company perspective, both effects lead to a wider innovation funnel due to more idea inflow compared to the original figure (Figure 4, rectangle area 3) – naturally assuming that resources are not a restraining factor in this consideration.

3.3.2 Idea evaluation and realisation

Ideas run through a permanent process of evaluation with diverse criteria where priorities are set or bad ideas are filtered. Because resource input is naturally a restraining factor in reality, only a few ideas are actually getting implemented. This process always takes place in each single company. Applied criteria are classically exclusively related to the single company. In case of a bilateral cooperation, influences from a second actor may also be considered. However, since Life Cycle Innovations involve several actors, the consequent integration of all relevant companies is urgently needed to foster the success of the innovation. In an integrated evaluation process, each company brings in additional and other evaluation criteria resulting from their own internal requirements on each innovation. Just one of many possible examples is the development of eco-innovations: a coordinative process between product developer and recycler can certainly lead to products that indeed ideally fit the requirements of recycling and optimize this phase – then again this bilateral perspective can evolve problems when it comes to acceptance of the customer (use phase), cost efficient production or redistribution aspects. Within the last years business life showed several examples were these problems actually occurred. Little mistakes, missteps, and delays in the innovation processes often cause negative effects that get each other going due to the creation of reinforcing feedback-loops. If a company forgets to notify one ore more actors of the extended supply chain network about a change in an innovation project, or inadequately communicates the information along the supply chain, it will slow down the innovation processes along the supply chain and thereby diminish the

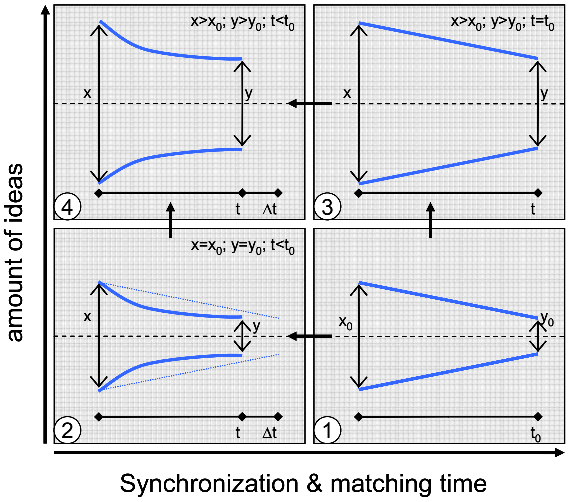

Figure 4. Potential Effects of Life Cycle Orientation in Innovation Processes

revenue and profits of the whole supply chain. In extreme cases, inadequate communication and synchronization of requirements between partners of the extended supply chain network can lead to economical or ecological failures, as the overall success of an innovation can not be measured before the innovative product leaves to its end-of-life stage.

Since insufficiently synchronized requirements and processes cause wasted time and development efforts, optimizations in innovation processes of extended supply chain networks lead to more efficiency in terms of time and resource input. With coordinated activities during evaluation phase, promising ideas are identified significantly faster because all potential problems in different life cycle phases are known earlier. This also leads to a more efficient filtering of innovations which are not worth any further consideration because of insuperable obstacles and avoids the use of unnecessary resources. Synchronization and matching of all relevant requirements is more efficient, thus a given amount of ideas can run through the funnel in less time. Additionally, the cooperation of diverse qualified specialists generally leads to more efficient processes regarding evaluation and also final implementation (e.g. experience sharing, concentrated resource allocation to overcome major obstacles etc.). Referring to the funnel model with a constant amount of ideas compared to the original figure, the funnel gets tighter in an earlier phase and is also shorter (Figure 4, box 2). Compared to the original situation resources are used more efficient which decreases their utilization and enables to deploy them in other projects. Due to better matching of all relevant requirements, innovations leaving the funnel are more mature through better requirement coordination and have a significantly higher success probability which also increases total effects of the innovation in the end.

Idealistically, there will be a combination of all effects: more and better innovations with higher success probability emerge in less time and with lower resource deployment. This results in higher innovation productivity (Figure 4, box 4). Further studies have certainly to be conducted to observe whether all these theoretically derived effects really appear contemporaneously in reality.

4 SIMULATION MODEL APPROACH

Qualitative analyses based on theory and case studies are an important way to gain understanding of the behaviour of innovation systems including their influencing factors and dependencies. However, for a very complex and dynamic system like an extended supply chain network predictions about the actual behaviour are hardly possible. Therefore the Life Cycle Innovation concept was transferred into a simulation model. This enables to verify assumptions and conclusions from the description framework and allows further analyses of the system to reveal potentials and trade off-effects of life cycle innovations. As a result, general recommendations for system design and basic strategies can be derived. With integrating detailed data from real networks, specific optimization experiements are also possible.

4.1 Basic Variables, Measurement and Goals

Every innovation within the extended supply chain network system is treated as a discreet object (entity) in the simulation and has its individual characteristics. Important basic entity variables are the complexity of an innovation and its potential to change respectively improve something with implementing it. The simulation approach directly refers to the Life Cycle Innovation model with its theoretical base. As a result the certain need for an amount of coordination of the specific requirements regarding its different life cycle phases/ actors is also an essential and specific value of each entity. The better these requirements are matched, the better the innovation can work as intended. The full potential can only be tapped when all requirements are considered. Since not every innovation is equally important or relevant for each actor of the system, another important variable is also its certain attractiveness from the perspective of each company. The effect of an innovation is the result of its intrinsic potential, the remaining demand for coordination and its attractiveness for the considered actor.

To actually carry out the coordination process each company has to provide resources (e.g. promoters) which interact on a virtual network layer within an innovation community. These resources are a restraining factor since they are normally contemporaneously responsible for several innovations with different maturity on different layers (company or network). Referring to an activity based costing approach using these resources generates costs dependent from the complexity and specific need of coordination of the innovation. Managing these resources includes allocation qualification and operational control through priorities and is a central factor to successfully and efficiently develop life cycle innovations. In the simulation model the amount of resources and their qualification can be configured through parameters of the company module (see below).

When analysing the system behaviour several relevant variables can be measured to evaluate the effect of certain strategies or structural changes. A simple example to evaluate the effectiveness of the innovation process is just the ratio of successful innovations to all innovations of the system. Additionally the generated costs during the process (which is interconnected with the throughput time of an innovation) and the final total effect of a ´finalised´ innovation (depending on the intrinsic potential and the degree of coordination) are very useful indicators. The ratio between these variables as an input to output consideration is a typical value which subsumes several aspects could serve as an appropriate target variable for optimization. However, other optimization targets are naturally also possible. To maximize the total effects of innovations, relatively higher costs may be accepted for example. Against that innovations do not necessarily have to be perfectly matched since the last percent often demand disproportionately effort and costs.

Depending on the purpose both global and local consideration can be useful for all variables. Global means the holistic view from the network level to optimize the whole system whereas the local view is focussing single actors to optimize their position within the system.

4.2 Model structure and procedure

The simulation approach directly refers to the Life Cycle Innovation framework with its theoretical base including the extended promoters model, the generic innovation process etc. Against prior simulation approaches in innovation research which often base on System Dynamics, discrete simulation is used and implemented with Anylogic 5.5™ here. To reflect the certain logical coherences which are based on the description model, standard elements of the simulation software were used and combined.

A basic requirement of the simulation approach is a mandatory flexibility which shall enable to adapt the model to different cases. Therefore, companies are modelled as generic object classes. Through parameterization these modules can reflect specific characteristics of different actors. As a result, complex networks structures of different companies can easily be created. Very basic parameters are the idea rate and the amount and qualification of resources which were allocated by this company for any innovation processes.

Innovations in the form of ideas are emerging within every single company of the network as discreet objects, each one with its individual set of characteristics which are getting randomly assigned. First of all every innovation has to pass an internal evaluation process which naturally seizes resources– if the idea is evaluated as not sufficiently attractive for its origin company it gets filtered out at once. In case of positive evaluation the innovation steps up to on the network level. On this level the coordination of all innovations and actors takes place. This means that specific innovations’ requirements regarding certain actors are reduced due to a matching procedure with the all other relevant companies in a successive multi-phase coordination process. Every phase of the coordination process is also modelled as object class with the option to set diverse parameters. Innovations with their specific coordination demand regarding different actors enter the phase and ´trying´ to seize resources from affected companies. If resources are available they are seized for a period of time. The duration of this period directly depends on the complexity and coordination demand of the innovation. After that the coordination demand regarding the companies that just provided resources is reduced. When achieving

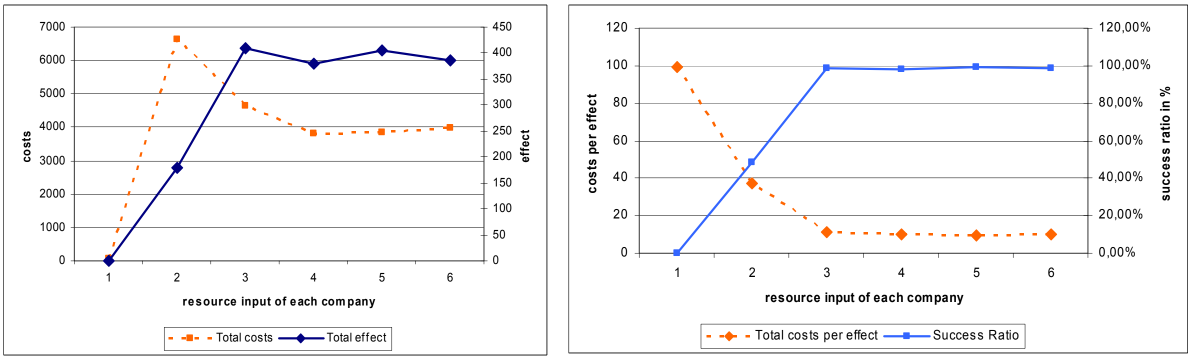

Figure 5. Effects of an increase in resource input on major indicators

a definable threshold over all coordination demands, the innovation enters the next coordination phases. Innovations that go through all phases (with decreasing filter thresholds) count as successful innovation. The abstracted concept with several filtering phases virtually depicts an innovation funnel on the network level. Finding the optimal thresholds and influencing this funnel is an important consideration for innovation strategy in the network. Questions like how much coordination is actually optimal or how fast coordination should be enforced can be addressed through this multiphase approach.

4.3 Simulation Experiments

Basic simulation experiments shall show the general behaviour of the system and enable to derive first recommendations. As an exemplary system a simplified extended supply chain network is considered here. It contains four actors representing tier, producer, user and recycler with a three-phase coordination process on the network layer. All following analyses mainly concentrate on the management of resources as they are critical aspects in the innovation process. When conducting simulation experiments only the considered variables are getting changed whereas all other parameters are constant. Since the actual amount of specific resulting values strongly depends on assumed figures (e.g. cost rates) the qualitative consideration of trends and comparison of alternatives is more important here.

Figure 5 displays the coherences between resource input of each company and some major indicators of the innovation performance seen from a global network perspective. Naturally resources are crucially needed for innovation processes but the results underline that there is a fast saturation effect. Assuming a similar amount of innovations that stochastically emerge in the system deploying more resource does not lead to a significant improvement of major target variables after reaching a critical point.

As shown above the actual matching of requirements on the network level takes place within successive coordination phases. The transition from one phase to the other is triggered by thresholds which stand for an achieved level of matched requirements. This enfolds several options to control the innovation process. One question is whether the perfect coordination of all actors is actually the best alternative whereas an ideal matching can cause disproportionately high costs. Secondly changing the number of coordination phases can also influence the innovation performance of the system – a specific degree of matched requirements can be reached in one target-oriented phase with concentrated and resource-intensive actions. Otherwise the same effect can be achieved with splitting coordination in several phases which levels both process and resource utilisation.

Figure 6 presents an abstract of relevant simulation results with different alternatives regarding the coordination process on the network level. The diagram exemplarily shows a typical curve (alternative 3) of the development of the ´costs per effect´ over the runtime which is an important indicator of innovation performance. The results are ambiguous and conflicts of goals show up – there is no single alternative which leads to optimal values for all major variables. Choosing an optimal coordination strategy strongly depends on the specific target variable. Considering the whole system for example, a concentrated and perfect coordination of requirements can cause the fewest cost - otherwise it bounds resources and disturbs the whole process which result in significantly less innovative output.

Alternative	**Matching of requirements**	**deployed coordination phases**	**Total costs per effect**	**Total effect**	**Total costs**	**Success Ratio**
1	perfect	three	57,21	62,86	3596	13,49%
2	perfect	two	37,77	175,24	6618	46,37%
3	high	three	37,13	178,53	6628	48,70%
5	high	two	44,39	149,52	6636	40,05%
6	perfect	one	23,71	37,36	885	8,80%
7	high	one	39,72	140,33	5573	39,90%
9	medium	one	35,64	171	6105	75,90%
10	high/medium	one	43,35	160	6941	47,30%
3a	*high*	*three*	*37,13*	*178,53*	*6628*	*48,70%*
3b	*high*	*three*	*80*	*318*	*25705*	*83,40%*

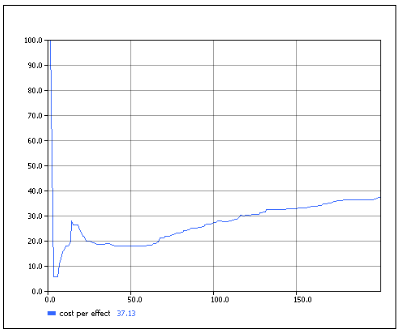

Figure 6. Results of simulation experiments regarding innovation coordination strategy

Whereas the derivation of clear recommendation is hardly possible and requires further studies on the basis of actual data, two hypothesises find support when looking at tendencies and correlations within the results.

- When resource availability is restricted, the perfect synchronization of all requirements is not always the ideal strategy especially when aiming at maximizing total effects of the innovation.
- Changing the amount of coordination phases has obviously also an important influence on performance. How to actually form the innovation process very much depends on the specific characteristic of the matching strategy.

As discussed before resources influence innovation processes within their company and on the network layer. Therefore priority strategies have also to be analyzed. Figure 6 show the results of simulation experiments. Simulation experiments with priority on the internal innovation process (3a) show no difference significant effects. Experiments with resources which prioritize innovations on the network level come up with interesting results: to improve external processes resources are the bottlenecks and so setting priorities on the network obvious lead to more and better innovations. In contrast to that costs are also significantly higher due to complex coordination processes with other actors.

5 SUMMARY AND OUTLOOK

In today's dynamic and complex business environment the efficient generation of successful innovations is crucial. Since innovations are more and more oriented to their whole life cycle in the sense of life cycle innovations, an isolated perspective on internal requirements is not sufficient. In fact an integrated coordination process including all life cycle phases which are represented by the actors of the extended supply chain network is a promising approach. This important perspective was not sufficiently considered in innovation research yet. Examples of innovations that failed in certain life cycle phases can not really explained with existing descriptions model. Therefore the Life Cycle Innovation framework was proposed in this paper which integrates and extends prior research work as well as practical experiences in a holistic description approach. The basic idea of a consequent integration respectively coordination of all relevant requirements within the life cycle can potentially lead to more and better innovations with less input of time and effort. To conduct further studies aiming to foster system understanding and to derive recommendation for optimal system design and strategies the theoretical framework was transferred in a simulation model. Simulation experiments showed some interesting results for an example of a network with four actors. However, to gain deeper insight more complex structures and the influence of variables like the qualification of promoters have to be analysed. Additionally the model itself can be further enhanced through the integration of external innovations as disturbance variable and the consideration of emergence effects on the network layer. To improve the model and derive recommendations for existing networks, realistic data should be used whereas the measurement of required variables in reality is certainly very difficult.

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