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**A causal model of the impact of the “fuzzy front end” on the
success of new product development**

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A causal model of the impact of the “fuzzy front end” on the success of new product development

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Abstract

In a study of New Product Development (NPD) projects, the fuzzy front end of innovation is explored. The New Product Development process is a multistage process. Therefore, the study examines two sorts of impact that the fuzzy front end has on the success of New Product Development: a direct impact and an indirect impact by influencing the next stage of the NPD process, i.e. project execution. Furthermore, the degree of newness of the NPD projects in accordance with the contingency theory, is considered.

We develop and test a causal model of relationships among key variables related to the fuzzy front end, project execution, and success. The causal model is tested with AMOS using information from 144 completed projects from German measurement and control technique firms.

For the most part, the responses from these firms support the hypothesized relationships. The frequently claimed importance of the fuzzy front end is confirmed. The results offer strong support for the importance of the early involvement of all functions in an NPD effort to enhance communication and ultimately project success. This can be advanced by a draft initial planning prior to development.

Furthermore, the responses highlight the importance of reducing market and particularly technical uncertainty during the fuzzy front end, both of which have a negative influence on communication and increase deviations during project execution. The technical uncertainty that remains at the start of the project has a direct, negative influence on project efficiency and overall it has the most far reaching implications for the success of the project.

With regard to contingency theory, the results indicate that effort spent on the reduction of uncertainty for improving project execution and project success may be influenced by the degree of newness. The degree of newness is found to influence the reduction of technical uncertainty, deviations from specifications, and efficiency.

Overall, the results of this study support previous research regarding the strong influence that front end activities have on NPD success. The model presented here provides several insights that can help managers to improve their NPD success and inspire researchers to carry out further studies regarding the fuzzy front end.

Introduction

The majority of German manufacturing firms develop new products (see Figure 1). Despite the importance of New Product Development, failure rates remain high [see, e.g. 1, 2, 3]. Therefore, researchers, as well as practitioners, are still trying to find ways to enhance the success of New Product Development. The “fuzzy front end” or “pre-development phase” is indicated as being one of the greatest opportunities to do so. Why should that be?

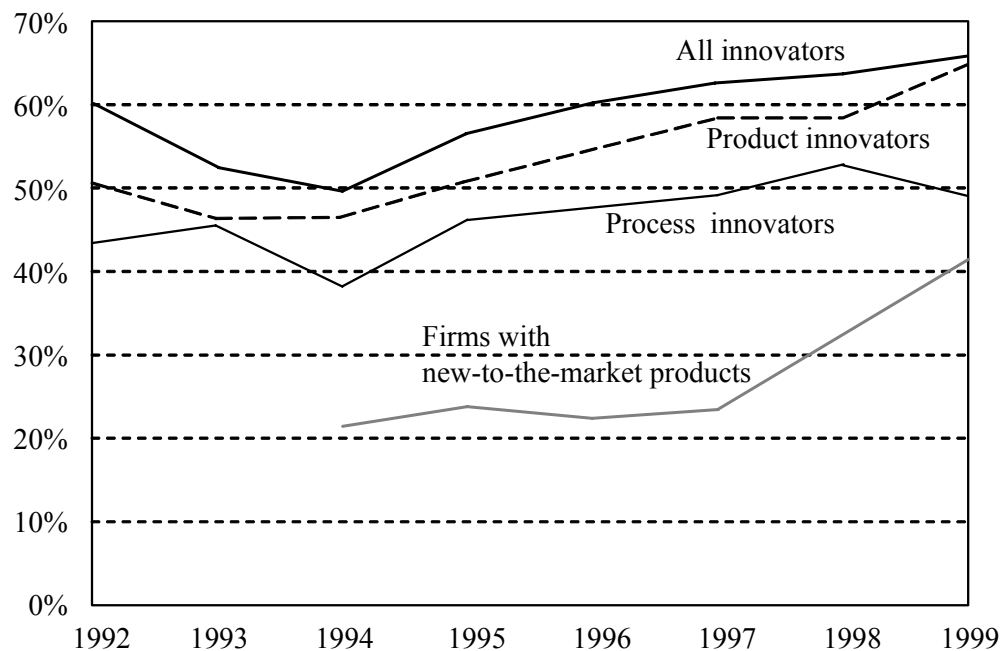


Figure 1: Percentage of innovators in German manufacturing firms [source: 4]

Firstly, several large scale studies highlight the importance of the fuzzy front end [e.g., 2, 5, 6]. Cooper and Kleinschmidt found that “the greatest differences between winners and losers were found in the quality of pre-development activities” [5]. Secondly, the fuzzy front end strongly determines which products will be developed in a firm [7, 8]. Thirdly, quality, costs, and time scales are defined to a large extent here [9]. The front end has the greatest potential for improvement with the least possible effort [10, 11, 12]. In addition, unclear goals and specifications like product specifications may lead to substantial delays [7, 13, 14]. A large scale study [15] reports that one third of the total development effort is caused by unnecessary changes. Last but not least, the fuzzy front end is one of the least well-known areas in innovation management [16].

In literature, the fuzzy front end first appeared in association with research into success factors. The fuzzy front end was predominantly restricted to one factor, e.g. “quality of pre-development activities” [17]. In addition, with few exceptions, contextual factors were neglected and only a direct influence on success was considered [18]. The supposed “leverage effect” suggests that the front end has an additional, indirect impact on project execution and hence NPD success. Although the number of publications related to the fuzzy front end has been increasing recently, most of the empirical studies are still explorative, e.g. case studies or benchmarking projects [e.g., 19, 20].

Overall, a quantitative confirmatory study of the direct and indirect influence that the fuzzy front end has on NPD success has yet to be published [8]. The aim of this paper is to address this gap by developing and testing a causal model. The development of the causal model is presented in the next section. The following section describes our research methodology and analysis. Finally, this paper discusses results, highlights managerial implications, and makes suggestions for future research.

Development of the causal model

Framework

The framework of this study and the factors and relationships explored were influenced by two research approaches: an information processing and a contingency approach. The contingency approach was developed within organization theory [21]. The contingency theory assumes that it takes different approaches to deal with various conditions. Several researchers suggest a contingency approach to NPD [13, 22, 23]. Depending on contextual factors, for example the degree of newness of a new product to a firm, different management approaches take on a different significance. Figure 2 applies the contingency approach to the fuzzy front end. The fuzzy front end directly influences project success. In addition, it influences project execution, which in turn fosters project success.

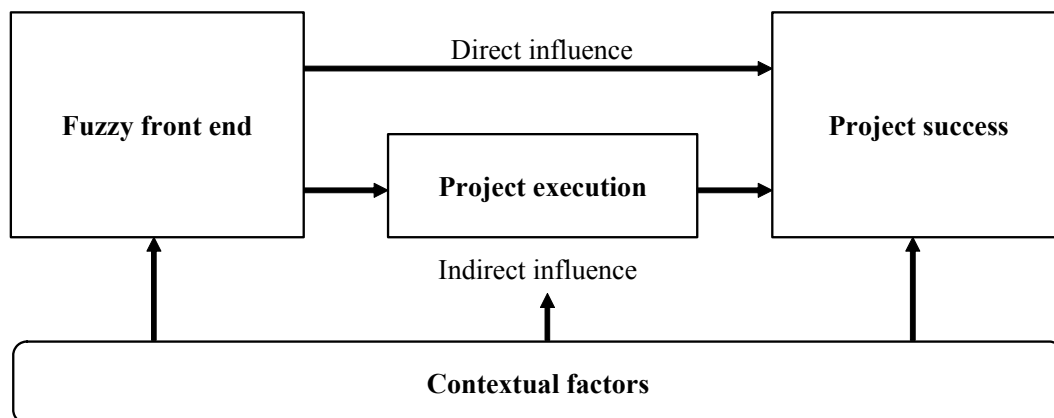


Figure 2: Conceptual framework of the study

Furthermore, product development and the processes behind it are seen as a series of activities related to problem solving. The more radical the product innovation, the more complex and iterative the problem solving process or the NPD process behind it. Typical risks jeopardizing the success of innovation for example, include inaccurate estimates of future market demand, failure to develop the adequate technology or in extreme cases, a combination of both.

In the NPD process, relevant information has to be gathered in order to reduce such risks and uncertainties [7, 24]. Uncertainty is defined as “the difference between the amount of information required to perform a particular task, and the amount of information already possessed by the organization” [25]. The more that a risk or uncertainty can be reduced during the front end of this process, the lower the deviations from front end specifications, during the subsequent project execution phases and hence, the higher the product development success. Uncertainties inherent in NPD projects relate to the market and technology [26].

Causal model

To detail the conceptual framework in Figure 2, based from an information processing perspective of the NPD process, we undertook an extensive literature review which included numerous studies and publications. This enabled us to identify important factors, relationships between these factors, as well as items successfully used in previous studies for its measurement. As there are no detailed large-scale studies about front end activities, we additionally considered exploratory studies and theoretical papers from innovation management, project management, and organizational theory literature. On the basis of this literature and exploratory interviews, the causal model shown in Figure 3 was developed.

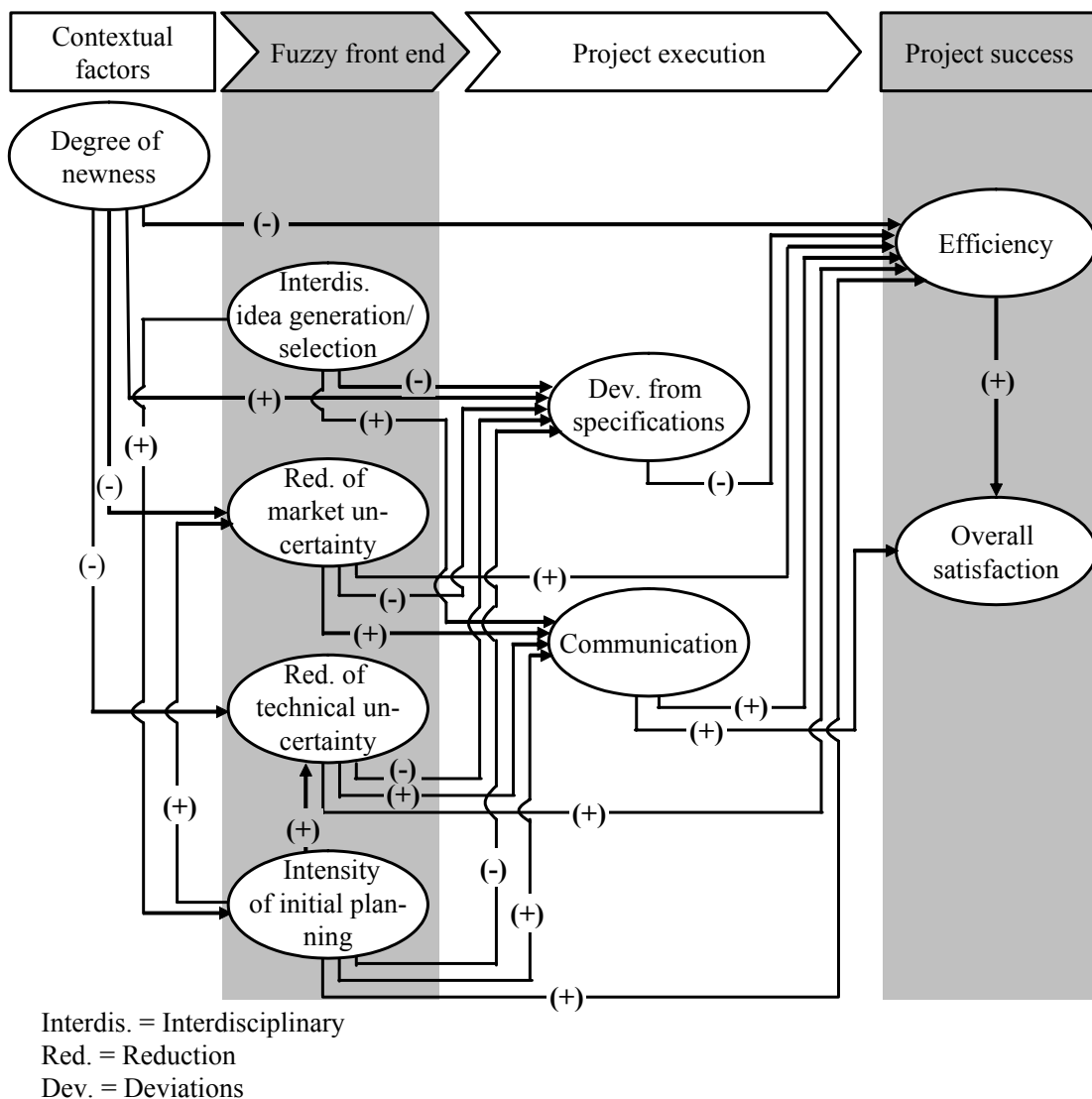


Figure 3: Detailed conceptual model of the study

Factors of the fuzzy front end

The model poses four key front end factors that improve communication and reduce deviations during project execution, which in turn determine efficiency and ultimately the Research and Development (R&D) managers’ overall satisfaction with regards to the project. The four front end factors are “Interdisciplinary idea generation and

selection”, “Reduction of market uncertainty”, “Reduction of technical uncertainty”, and “Intensity of initial planning” prior to development.

The factor “Interdisciplinary idea generation and selection” includes the process of incorporating different functions into the generation and selection of new product ideas. Idea generation is a combination of an organizational need, problem, or opportunity with the purpose of satisfying this need, solving a problem, or capitalizing on an opportunity. The idea assessment phase is critical in being able to decide which ideas are to put forward for development. Given that decisions frequently have to be made without having all of the relevant information at hand, idea assessment is a necessary step in the innovation process, but it is accompanied by a high degree of uncertainty. The more radical the innovation project, the more difficult it becomes to make an early assessment of an idea. Therefore, most researchers favour using an interdisciplinary group for idea generation and selection [27, 28]. R&D and marketing, as well as other functions (e.g., production, customer service) should cooperate early on in this creative process. Such a multidisciplinary integration ensures that customer needs and technological capabilities are taken into sufficient consideration, even in the early stages of the innovation process [28]. A mutual understanding and shared goals concerning the innovation, early on in the process will enhance the information transfer between departments and therefore reduce uncertainties.

After selecting an idea to be worked out in more detail, market uncertainty has to be further reduced, which should lead to a more in-depth understanding of the market. The factor “Reduction of market uncertainty” refers to knowledge about target markets, target customers, user needs, market potential, and market attractiveness prior to development. Given that there are several ways to reduce market uncertainty during the fuzzy front end and different methods and tools can be applied, it was decided only to measure the outcome of these activities; market information, that was available prior to the start of development.

This information processing perspective was also applied to the measurement of technical uncertainty. Following Cooper and Kleinschmidt, the factor “Reduction of technical uncertainty” refers to specification of technical requirements and feasibility checks prior to development [29]. Several studies indicate that early reduction of technical uncertainty has a strong influence on project success [29, 30, 31].

When the overall objective of a NPD project is clear, the initial planning prior to the start of the development of the new product translates the overall project goals into a series of activities with a clear allocation of resources for each. Although some information needed for planning may at that point in time be difficult to forecast, overall uncertainties are reduced by laying out a draft process from development to product launch. Several large scale studies suggest that comprehensive planning contributes significantly to the success of projects [22, 32, 33]. The first step of initial planning is to break the product development project down into various work packages. Thereafter, timescales, resources and overall responsibilities are allocated to each of the work packages [10]. The factor “Intensity of initial planning” refers to the intensity of these activities prior to the start of development.

Factors of project execution

To represent the product development phase between the fuzzy front end and the launch of the new product, we focused on two factors which are strongly influenced by fuzzy front end activities: “Deviations from specifications” defined during the

fuzzy front end, and “Communication” within the product development team as well as between marketing and R&D.

The factor “Deviations from specifications” includes a range of items, such as changes in the technical concept or project goals. Changes may be necessary to adapt to requirements like changing customer needs or technological advances in a dynamic environment. Nevertheless, studies report that most of the changes made during project execution are avoidable and unnecessary [e.g., 15]. Consequently, several studies show that well-defined deliverables and procedures during the fuzzy front end reduce deviations from these specifications during project execution and therefore foster project success [33, 34, 35].

Success measures

Finally, two factors represent NPD success at the project level: “Efficiency” and “Overall satisfaction”. Success measures have been thoroughly analysed in literature [e.g., 36, 37, 38, 39, 40]. Nevertheless, researchers still use divergent measures [36]. Recurring questions occur as to when success should be measured and who should assess the success of a NPD project [36]. Regarding the point of time at which the measurement takes place, we asked respondents to describe the development of the last product brought onto the market (last-incident method). To assess “Efficiency”, compliance with time, financial, and personnel resources planned during the fuzzy front end was assessed by the respondents [37, 38, 39, 40]. In addition, we used a deliberately subjective factor: R&D managers’ “Overall satisfaction”. We chose this factor for two reasons. Firstly, R&D managers are key people in rather technically driven NPD projects in the measurement and control sector which we explore in this study. Secondly, satisfaction of R&D managers with team work, the development process, and the outcomes of a NPD project determines their future attitude towards NPD, and therefore their performance on future NPD projects, e.g. interaction with other departments [41]. Hence, in the long run, key people’s “Overall satisfaction” enhances the firms’ ability to successfully develop new products.

Contextual factors

With regard to contextual factors, we focus on one industry sector in one country to reduce the number of relevant contextual factors and therefore the complexity of the study. Literature has identified the degree of newness of a NPD project for a firm as being a key contextual factor [e.g., 3, 13, 30, 40]. In particular, as we are taking an information processing approach to new product development, the degree of newness determines how much information must be gathered by a firm to develop a new product. A high degree of newness makes it more difficult to reduce market and technological uncertainty [30]. In addition, we measured and then evaluated the influence that a firm’s size had on the results.

Basis hypotheses

As this would go beyond the scope of this paper, the 22 hypothesized relationships shown in Figure 3 will not be described in detail in this section. They will be discussed later within the scope of the results of our study. The four basic hypotheses of our study can be summarized as follows:

H1: Front end factors are interrelated.

H2: Front end factors have a direct influence on success.

H3: Front end factors have an indirect influence on success.

H4: The degree of newness has a direct and an indirect influence on success.

Research methodology and analysis

Data collection procedure

The factors were obtained from literature and exploratory interviews. The factors were verified during a pilot study by using a standardized questionnaire. The literature was reviewed for previously used items that describe the factors of our model. As several items had to be translated into German, in particular the interpretation of the questions was verified, during the exploratory interviews and a mailed pre-test. The pilot study and pre-test should insure content validity. The hypothesized causal model was examined using the revised standardized questionnaire which was sent to all research and development managers of measurement and control firms identified from two corporate databases in Germany (full survey). From 731 firms, 154 returned the questionnaire and 144 data sets could be used for analysis. Comparisons of average values did not identify big differences between those questionnaires that were returned early and those that were returned later, so we do not assume a significant non-response bias [42]. Respondents expressed their perception of each item using a Likert-type scale of 1 to 7, where 1 is “strongly disagree” and 7 is “strongly agree”.

Respondents

The size of the firms in the sample ranged from having 30 to 6700 employees and annual sales ranging from 1 billion DM to 800 billion DM. Most of the firms in the sample are Small and Medium sized Enterprises (SMEs), which is representative of the measurement and control sector in Germany. The firms produced sensors, measuring instruments, control elements and units, and electrical parts. For the purpose of this study, interviewees were asked to describe the development of the last product brought onto the market (last-incident-method). This definition includes the modification of existing products. However, as shown in Figure 4, most of the new products studied here were medium or highly innovative, which reflects how German measurement and control firms are market leaders with regard to NPD. An overall assessment of the degree of newness (left part of Figure 4) and a classification of the product concept (right part of Figure 4) deliver similar results regarding the degree of newness of the new product concept to the firm.

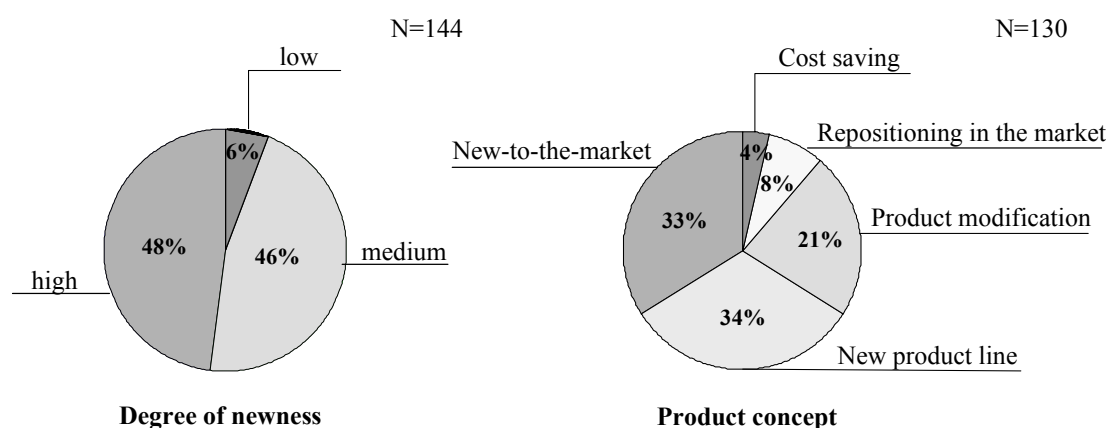


Figure 4: Degree of newness of the new product concepts to the firms

Measurement Validation

The reliability of each factor was assessed in the following manner. Firstly, traditional reliability measures were used. Items with a low item to factor loading were deleted and Cronbach alpha of each factor was calculated. This step led to minor modifications of the factors which all showed sufficient reliability. Secondly, the slightly revised factors were integrated into a measurement model and tested with AMOS. We follow the two-step approach recommended by Anderson and Gerbing [43]. Firstly, the measurement model is estimated and secondly the measurement model is estimated in conjunction with the structural model. Due to the small sample size (N=144) and predominantly non-normal distributed variables, we chose Unweighted Least Squares estimation (ULS) instead of the, at least in principle, preferable Maximum Likelihood estimation method (ML) [43, 44, 45]. Using the estimation results, the reliability of the whole measurement model and the reliability, and discriminant validity of factors and items was assessed. Table 1 summarises some of the lower limits used for measurement validation. With all but a few exceptions, requirements were fulfilled and therefore no further re-specifications were made. The results suggested that the measurement model adequately fits the data and that testing the structural model is appropriate.

Criterion	Limit
Whole model:	
GFI	≥ 0.9
AGFI	≥ 0.9
NFI	≥ 0.9
RFI	≥ 0.9
Measures:	
Indicator reliability	≥ 0.4
Factor reliability	≥ 0.6
Average variance for each factor	≥ 0.5

Table 1: Limits for measurement validation [source: 46]

Model testing and estimation

The results of the AMOS analysis of the hypothesized causal model are summarised in Figure 5. The fit indices AGFI, GFI, NFI, and RFI exceed 0.90. Therefore, the overall fit of the model is satisfactory. Of the 22 relationships tested, only four were rejected (see dotted lines in Figure 5). This indicates a sufficient validity of the model. Figure 5 presents standardised path coefficient estimates for the hypothesized relationships of the conceptual model presented in Figure 3. Measures and reliability and interconstruct correlations are given in the Appendix. With a few minor exceptions, results indicate that the reliability and discriminant validity of the measures are satisfactory. Overall, the confirmatory analysis was successful and therefore results can be discussed in the next section.

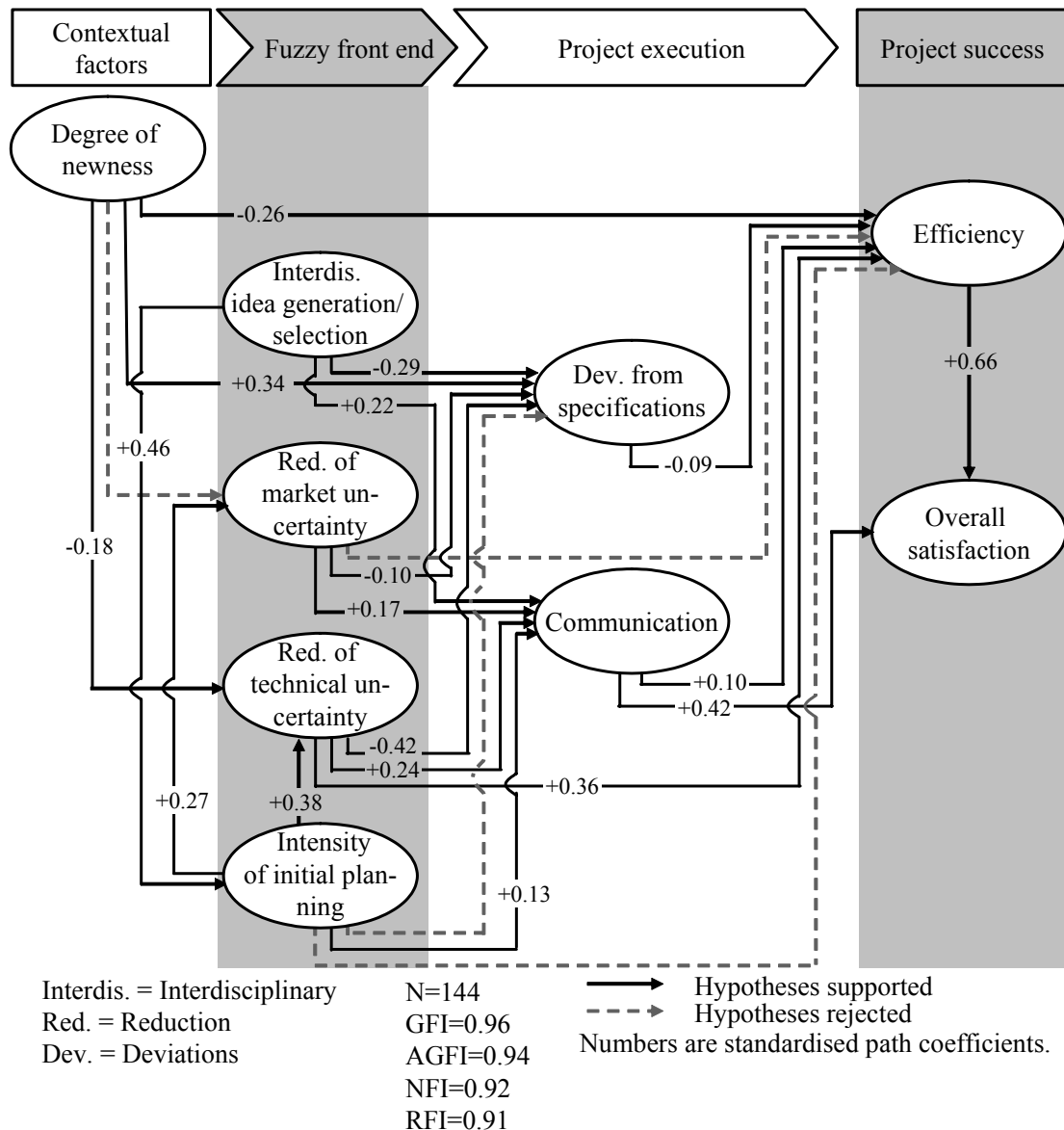


Figure 5: Causal model tested with AMOS

Results and discussion

The results presented in Figure 5 reconfirm the broad importance of front end factors. Most of the hypothesized relationships between front end factors and project execution and project success are supported. In addition, the contingency theory prediction is reinforced. Firstly, a high degree of newness makes it more difficult to reduce uncertainties during the front end, secondly, it increases deviations from specifications during project execution, and thirdly, it has a negative impact on efficiency.

The four front end factors and the “Degree of newness” provide an explanation for 40% of “Deviations from specifications” and 25% of the quality of “Communication” during project execution – squared multiple correlations (smc). These results provide substantial support for the widely assumed “leverage effect” that the fuzzy front end has on the further development process.

In summary, the causal model explains 34% of “Efficiency” and 76% of R&D managers’ “Overall satisfaction” (smc). Given that it was not the objective of this

study to identify all of the factors influencing project success, these values exceed expectations. After summarizing these key findings we now discuss the four basic hypotheses in detail.

Interrelationships between front end factors (H1)

The results of our study reinforce the assumption, that front end factors are interrelated. All three hypotheses about interrelationships between front end factors are supported. Bringing people together from different functions early on in the process enhances front end planning. Intensive initial planning helps to reduce market and technological uncertainty. In terms of initial planning, the indirect effect on project execution and project success is even stronger than that of the direct effect (see Table 2 and 3).

Direct effect of the fuzzy front end on project success (H2)

From the three hypothesized direct effects, only the direct effect of the reduction of technical uncertainty on efficiency is supported. The reduction of market uncertainty and intensity of initial planning show no direct effect on efficiency.

Indirect effect of the fuzzy front end on project success (H3)

Table 2 and 3 reports direct, indirect, and total effects of contextual and front end factors on the further development process and on project success. Several indirect effects can be observed which are often stronger than direct effects.

Contextual and front end factors	Direct effect → Deviations	Indirect effect → Deviations	Total effect → Deviations	Direct effect → Communication	Indirect effect → communication	Total effect → communication
Degree of newness	+0.34	+0.08	+0.42		-0.04	-0.04
Interdis. idea generation / selection	-0.29	-0.09	-0.38	+0.22	+0.12	+0.34
Red. of market uncertainty	-0.10		-0.10	+0.17		+0.17
Red. of technical uncertainty	-0.42		-0.42	+0.24		+0.24
Intensity of initial planning		-0.19	-0.19	+0.13	+0.14	+0.27

Table 2: Direct, indirect, and total effects on project execution

Contextual and front end factors	Direct effect → Efficiency	Indirect effect → Efficiency	Total effect → Efficiency	Direct effect → Satisfaction	Indirect effect → Satisfaction	Total effect → Satisfaction
Degree of newness	-0.26	-0.37	-0.63		-0.26	-0.26
Interdis. idea generation / selection		+0.13	+0.13		+0.23	+0.23
Red. of market uncertainty		+0.03	+0.03		+0.09	+0.09
Red. of technical uncertainty	+0.36	+0.06	+0.42		+0.38	+0.38
Intensity of initial planning		+0.18	+0.18		+0.23	+0.23

Table 3: Direct, indirect, and total effects on project success measures

In order to reduce uncertainty and ambiguity, information is processed and various activities are coordinated during the NPD process. Members from different functions however may interpret the same events differently or might be pursuing different priorities or goals, and hence some conflicts may occur here. A quickly developed team vision, a shared purpose and plan of action that clarifies clear and realistic project targets all help to create a sense of commonality [8]. If all functions are integrated at the beginning of the process, i.e. during idea generation and assessment, a common vision and goals are developed and hence, communication is improved and fewer conflicts occur during project execution. In summary, an interdisciplinary approach to idea generation and selection has the greatest impact on enhanced communication during the latter process of all front end factors in this study. Furthermore, as information is shared early on in the process, fewer deviations occur during project execution.

The reduction of market and technological uncertainty before the start of the cost intensive development phase directly reduces deviations from targets specified during the fuzzy front end and improves communication within the project team and between key functions like R&D and marketing. In our study, the reduction of technical uncertainty has a greater impact than market uncertainty, which could be explained by the technical character of the projects analysed.

At first glance, the results for the factor “Intensity of initial planning” are counter-intuitive and not in line with former studies [e.g., 22, 32, 34, 38, 47]. The “Intensity of initial planning” has a slightly positive influence on “Deviations from specification” and does not enhance project efficiency. However, by integrating indirect effects plus

the positive impact on communication, all in all, an intensive front end planning enhances efficiency and leads to a higher satisfaction. In contrast to former studies, we have focused on the initial planning step before the start of development. In many NPD projects, as uncertainties are high during the fuzzy front end, only draft plans are made at the beginning of the process and details are added during the course of the project, as tasks become clearer [47, 48]. The role of initial planning seems to be less directly linked to efficiency. Instead, an intensive front end planning helps to develop a common understanding of project tasks and milestones and therefore reduces uncertainty and conflicts between functions. Hence, communication within the project team and between different functions can be improved by adding an initial planning step.

Effect of contextual factors (H4)

Except for one hypothesis, all relationships hypothesized for the degree of newness are supported. A high “Degree of newness” directly increases “Deviations from specifications” and decreases “Efficiency”, regardless of activities undertaken during the fuzzy front end. In addition, a high degree of newness makes it more difficult to reduce technical uncertainty. This is not the case for the reduction of market uncertainty. As already discussed, this could be explained by the fact that most of the new products included in this study were technology driven and targeted at existing markets or customers.

In addition, we looked at the effects that firm size has on front end factors, project execution, and project success. Regression analysis did not reveal any influence of the number of employees or annual sales of the firms studied on the factors of our model.

Key drivers of success

“Communication” and “Efficiency” account for 76% of the R&D managers’ “Overall satisfaction” (smc). In summary, these two factors have the strongest influence on “Overall satisfaction”, followed by the “Reduction of technical uncertainty”. The other factors all have a similar influence on “Overall satisfaction”, except for the “Reduction of market uncertainty”, which has no significant influence on “Overall satisfaction”. This can be explained by the fact that the projects studied are technology driven, and that the R&D managers’ overall satisfaction is assessed, which have a more technical than market related focus. In addition, the variance of factor “Reduction of market uncertainty” is rather low.

“Efficiency” in turn is strongly determined by “Reduction of technical uncertainty”, and the “Degree of newness”. “Interdisciplinary idea generation and selection”, “Intensity of initial planning”, “Deviations from specifications”, and “Communication” follow next in importance.

Summary and conclusions

Summary of results and limitations of the study

The results of this study provide more evidence to previous research regarding the strong positive effect of fuzzy front end activities on NPD success. The presented model has enabled us to enhance our understanding of the dynamics of the fuzzy front end. It helps to explain direct and indirect effects, and provides several insights that will help managers to improve the success of their NPD activities

The results reinforce the overall importance of communication within a New Product Development team and between R&D and marketing. It was observed that R&D

managers' overall satisfaction with team work, the development process, and project outcome was largely attributed to communication.

The results reported here, as well as elsewhere [7, 12, 13, 28, 49, 50], significantly support the importance of early involvement of all functions in an NPD effort to enhance communication and project success. The results reveal the relative weighting of initial planning for developing a mutual understanding and therefore improving communication later in the NPD process. The direct relationship between overall planning activities and efficiency observed in previous studies was not supported. These results indicate that planning activities both early and later in the NPD process may fulfill different purposes. This would explain and justify the variation of results reported in literature from a high to low or no effect of overall planning on efficiency [22, 32, 34, 38, 47].

Consistent with previous research, this study found positive effects of reducing both technical and market uncertainty on project execution, measured by deviations from specifications and communication. Furthermore, reducing technical uncertainty was found to be important for efficiency. A similarly hypothesized relationship was not supported for the reduction of market uncertainty. A possible explanation for the rejection of the hypothesis in terms of market uncertainty could be attributed to the technology driven nature of the NPD projects studied from the point of view of R&D managers, and a low variance of the factor.

Furthermore, the results indicate that the effort spent on the “Reduction of (technological) uncertainty” for improving project execution and project success may be influenced by the “Degree of newness”, which was found to influence the “Reduction of technical uncertainty”, “Deviations from specifications”, and “Efficiency”.

Although our study increases our understanding of the fuzzy front end of New Product Development, there are several limitations. Firstly, because uncertainty and success measurement is known to be problematic [36, 38, 39, 40], suspicions are naturally aroused about the adequacy of the measures used. Although the measures used here, met acceptable reliability requirements, they could be improved. Secondly, due to our focus on the measurement and control sector, most of the projects in our study were technology driven. Therefore, the variance of the factor “Reduction of market uncertainty” was low. This may account for the low path coefficient with regard to the reduction of market uncertainty.

Last but not least, our study has several weaknesses related to ex-post measurement and structural equation modeling which have already been extensively discussed in previous research [e.g., 36, 38, 39, 40, 51]. For example, we only measured R&D managers' perception of reality [39, 51]. Furthermore, causality is something that cannot be proved within the scope our study. We only tested if we had to reject our conceptual model, based on former research. Directionality of the relationships could be reversed in some instances.

Managerial implications

Based on our results, recommendations for NPD managers are presented. Most of the factors enhancing NPD success can be influenced by management. The results suggest that all functions should be integrated as early as possible in the NPD process to develop a shared purpose and plan of action that clarifies realistic project targets, and creates a sense of commonality. This process can be supported by an initial planning which drafts tasks, milestones, and resources.

The results suggest that NPD managers should consider emphasizing the "Reduction of technical uncertainty" when there is a need to improve either "Deviations", "Communication", "Efficiency", or the R&D managers' "Overall satisfaction". Furthermore, the results indicate that the effort spent on the reduction of technological uncertainty for improving project execution and project success may be influenced by the degree of newness. Technical uncertainty can be reduced by feasibility studies and setting up clear technical specification with regard to the product and the production process.

In conclusion, the joint emphasis of all front end factors studied with consideration of the degree of newness thus appears to represent a powerful combination for promoting NPD success.

Suggestions for future research

Our findings form the groundwork for future research about the fuzzy front end. This study has highlighted the need for future research that focuses on the development of valid and reliable measurement instruments for front end factors, especially for the reduction of technical and market uncertainty. Our study indicates that planning may fulfil different purposes throughout the NPD process. Future research could explore this proposition in more detail. Reduction of market uncertainty during the fuzzy front end is worthy of further research, especially by selecting projects which are targeted at new markets or customers. For this purpose, studies of the fuzzy front end should be extended to different industry sectors. Ideally, to overcome the limitations of our study, future studies should be cross-national and should collect longitudinal data, which is admittedly difficult to obtain.

APPENDIX: MEASURES, RELIABILITY, AND VALIDITY

Factor	Indicator	Indicator reliability	Factor reliability	Average variance
Overall satisfaction	Satisfaction within team	0.31	0.73	0.48
	Satisfaction with process	0.71		
	Satisfaction with results	0.43		
Efficiency	Milestones achieved	0.52	0.67	0.54
	Personnel targets achieved	0.48		
	Cost targets achieved	0.61		
Deviations from specifications	Changes to the technical concept	0.60	0.78	0.55
	Deviations from planned procedures	0.63		
	Change of project objectives	0.41		
Communication	Communication within team	0.35	0.74	0.59
	Communication between R&D and marketing	0.84		
Interdisciplinary idea generation and selection	Interdisciplinary idea generation	0.35	0.77	0.53
	Interdisciplinary idea selection	0.72		
	Idea selection during meeting	0.51		
Reduction of market uncertainty	Target market and user needs well understood	0.45	0.63	0.46
	Market attractiveness and potential well understood	0.47		
Reduction of technical uncertainty	Definition of technical requirements	0.41	0.65	0.49
	Technical feasibility verified	0.56		
Intensity of initial planning	Work packages defined	0.70	0.88	0.65
	Timings allocated	0.72		
	Resources allocated	0.67		
	Costs projections made	0.51		
Degree of newness	Capital needs	0.55	0.65	0.49
	Overall skills	0.42		

Table 4: Measures and reliability

	Degree of newness	Interdisciplinary idea	Red. of market uncertainty	Red. of technical uncertainty	Intensity of initial planning	Deviations	Communication	Efficiency	Overall satisfaction
Degree of newness	1.00								
Interdisciplinary idea	0.00	1.00							
Red. of market uncertainty	-0.08	0.13	1.00						
Red. of technical uncertainty	-0.18	0.18	0.12	1.00					
Intensity of initial planning	0.00	0.46	0.27	0.38	1.00				
Deviations	0.42	-0.27	-0.15	-0.45	-0.09	1.00			
Communication	-0.06	0.34	0.26	0.35	0.37	-0.21	1.00		
Efficiency	-0.37	0.13	0.16	0.49	0.20	-0.39	0.27	1.00	
Overall satisfaction	-0.27	0.23	0.21	0.47	0.29	-0.35	0.60	0.77	1.00

Table 5: Interconstruct correlations

The Fornell/Larcker criteria is not fulfilled for efficiency and satisfaction due to the strong correlation between the two. As this strong correlation is plausible, a sufficient discriminant validity between efficiency and satisfaction is assumed.

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