Technologie- und Innovationsmanagement

Working Paper

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October 2006
Working Paper No. 44

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Effectiveness of R&D project selection in uncertain environment: An empirical study in the German Automotive Supplier industry

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This paper presents results of an empirical large-scale study on uncertainty reduction of R&D projects and R&D project selection. The empirical field is the German automotive supplier industry. We explore R&D project selection practices in this specific industry and briefly contrast our findings with the academic research and management literature in this field. We concentrate on answering three research questions (with focus on questions no. 1 and 2):

I. Which information and related uncertainties are crucial for the product selection decision to the R&D decision makers?

II. How do R&D decision makers today cope with typical challenges related to reducing uncertainty? Where do they face major problems and how effective are they?

III. What are major implications for managing the Fuzzy Front End (FFE) of innovation process in industry practice and respectively for further academic research in this field?

Key findings are that on the one hand certainty about fields of product applications, target markets and production feasibility are most important criteria for initial product selection decisions. On the other hand market and cost related uncertainties (e.g. sales volume, product price, cost per unit) cannot be satisfyingly reduced in practice before project approval for development or definite termination of projects.

Although different uncertainty profiles exist within the process of project evaluation, most companies do not systematically choose available product selection methods and tools according to specific uncertainty situations. Intuition still plays a major role in R&D product selection.

Some first conclusion drawn from this research are: A sufficient level of resources (including financial and methodological know-how), a systematic use of suitable project selection instruments, and a fit with the company specific as well as the OEMs´ product/brand strategies can be potential levers for more effective uncertainty reduction before product decision.

1. Introduction

According to Booz-Allen & Hamilton, one of four projects that enter the development state become a commercial success[1]. Many studies demonstrate that R&D managers´ product decisions[2] at the fuzzy front end[3] (FFE) of innovation can have more impact on product success than at any other stage.[4] The reason is simple:

1 See (Booz-Allen & Hamilton, 1982)

2 In this article we focus on the (selective and resource affecting) go/no-go decision to start the realization of a specific product, i.e. its approval for development or its termination

3 The fuzzy front end describes the initial phase of the NPD process and includes idea generation, initial screening and evaluation of the project until its approval for development or its termination (see Cooper, 1988 or Herstatt, 2003).

4 E.g. Cooper (1992) concludes that the key decision at the front end of the innovation, the selection of the "right" product idea to be further developed and implemented into the market, becomes a critically important task.

While a great majority of projects are probably unsuitable for commercialization and many other failures are the result of bad execution, others are simply bad projects to begin with. Often the decisions for these projects result from wrong or missing information according high uncertainty during the FFE. As Cooper and Kleinschmidt (1986) found out quite early, many companies do not sufficiently try to close this information gap, e.g. by adequate market assessment, before the product decision is made – with profound consequences: Wrong product decisions can often only be corrected with significant financial effort later on.

Although research on success factors in innovation management since 1980s has confirmed the importance of "initial screening" at the FFE for the whole innovation process[5] and although it has been found out that resource investment in this phase pays off[6], research on this field does not give many hints on operational implementation (e.g. concrete methods and tools).

In contrast, the project selection literature suggests a large variety of different theoretical models for selection, priorization and valuation of innovation ideas[7], but does not provide a satisfying answer how successful these instruments are and to which extent they are used in practice. Current studies which investigate the success of model application in project selecting for a specific industry – and thus combine both fields of research – are very rare.

Consequently, industrial practice is still lacking workable and proven tools – especially the problem of information uncertainty at the FFE is still not solved.

With this empirical study we like to contribute in closing this gap in research as well as in practice. We choose the German automotive supplier industry as our empirical field of our analyses for two reasons:

Firstly, the German automotive industry is definitely a highly innovation driven industry in a very competitive environment with increasing pressures on each company. Secondly, there is no recent study available which draws a representative picture of the use of such tools[8] – although selecting the "right" innovation idea is still one of the greatest challenges in automotive R&D management. Very high failure rates in NPD, especially in this industry[9], support this assumption. Thirdly, this industry is of high economic relevance for Germany and worth to be looked at closer.

2. Methodical aspects

Based on the results of our intensive literature research on the field of uncertainty within R&D project selection and 12 explorative expert interviews with R&D managers of various automotive supplier companies and OEMs we developed a standardized questionnaire to assess the role of uncertainty as well as the use and the success of methods used by companies to select and evaluate an innovation project.

Sample

We asked 574 R&D managers of German automotive supplier companies to answer a series of questions concerning the last innovation project for which a go/no-go decision was made within their company (last-incident method). The criterion for being included was the company's listing in the German Hoppenstedt directory of 2004 as "automotive supplier" with a revenue p.a. of more than 5 million EUR and/or more than 50 employees. Furthermore only such companies were included in our analyses having their own R&D budget of at least 100.000 EUR. This filter led to an sample of N=96 companies, which allowed us to draw a satisfyingly representative picture of the project selection process within this industry, the related perceived uncertainties and the way the companies cope with these. Our sample of respondents is representative for the (rather medium-sized) German automotive supplier industry with regard to size, revenue, and R&D budget.

5 Particularly the research of Cooper and Kleinschmidt in the 1980s and 1990s (e.g. Cooper and Kleinschmidt, 1986, 1987, 1993, 1995) emphasize initial screening as one important success factor within innovation process

6 See Verganti, 1999

7 For an overview see e.g. Baker (1974), Souder and Mandakovic (1986), Ramsey (1986), Martino (1995), Ozer (2004)

8 As Stummer and Günther (2003) show in their meta analysis, especially in the highly innovation driven German automotive industry relatively little empirical research on the practical use of project selection (models) has been carried out so far.

9 According to a German automotive OEM´s post-project calculation more than 70% of its total innovation budget for its last passenger car project have been spent on innovation projects which finally have not been realized in the end product.

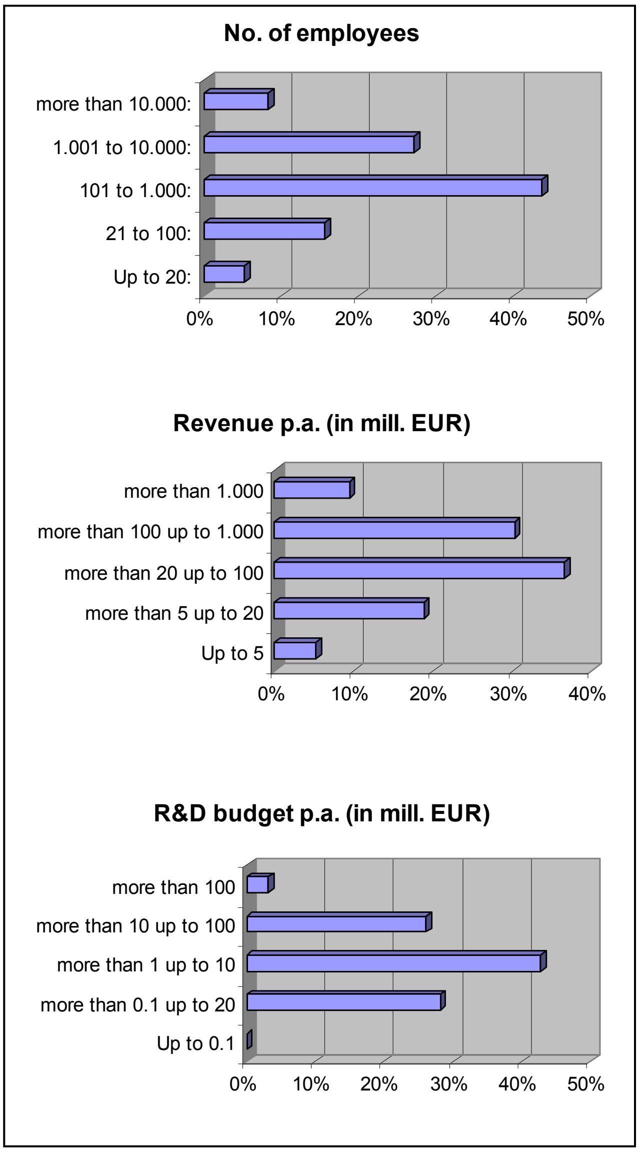

Fig. 1. Number of employees, revenue p.a., and R&D budget of companies within sample, 2005 (N=96).

Questionnaire

Most of our questions were designed to better understand the most recent project decision (last incident approach) and besides, it covered a number of company or organization related questions. The questionnaire roughly consisted of five pages and was divided into four sections:

(I) General questions about the company and its innovation process,
(II) Specific questions about the project for which the last go/no-go decision was made,
(III) Questions about (perceived) importance and actual information disposability (and resulting information uncertainties) on several dimensions before and after the project evaluation and selection process, and
(IV) Resources, methods/tools available and/or used within the project evaluation and selection process.

A pre-test with 12 industry experts was carried out to verify the questionnaire. In addition the Centre for Survey Research and Methodology (ZUMA) in Mannheim supported us in designing the questions and checked the quality of our final questionnaire.

Success variable

In order to assess the success of the information gathering and evaluation process, respectively the methods/tools used in order to prioritize projects before the final product decision, we had to agree on a dependent variable as a measurement of effectiveness of this phase. Measures of success have been thoroughly discussed in literature.[10] One often used variable, for example, is the "overall product success"[11].

We decided not to use this variable because of its limited value for our research question and looked for a different approach - for two reasons: Firstly, problems of appropriately operationalizing the variable "overall product success" have been extensively discussed in research[12]. Secondly, this variable is timewise far to distant from any initial project selection, which is typically taken in the very beginning of the FFE. That implies that many other factors besides project selection, e.g. the quality of execution, could influence the final success.

Therefore we tried to find a measurement which on the one hand accurately describes the target of the decision beeing made and on the other hand can be seized right after the product decision has been made.

Decision theory confirms that the "information gathering process" or "intelligence process"[13] is in general an important step towards a decision. [14] Simon (1977) describes the main focus of this phase as surveillance of the (economic, technical, political, and social) environment. Niggemann (1973) just calls it "information phase".

The same applies to the project evaluation and selection process (specifically to the phase between the two steps of FFE "having the idea" and "making the product decision") since this ends up in a (project) decision, too. Hence, the (phase of) information gathering seems to be an essential input dimension of any project decision.

In this paper we call this phase of information gathering and project evaluation before product decision[15]

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10 See e.g. Hauschildt (1991), Pinto and Slevin (1988), and Ernst (2001)

11 See e.g. Hauschildt (1991) or Herstatt, Stockstrom and Nagahira (2006)

12 Either the success variable is operationalized by a mixture of "hard figures", e.g. sales, profit, market share etc. (see Herstatt, Stockstrom and Nagahira. 2005), or the success is subject to individual judgement of one or more informants, e.g. the product manager – both alternatives seem to be problematic in the context of our study.

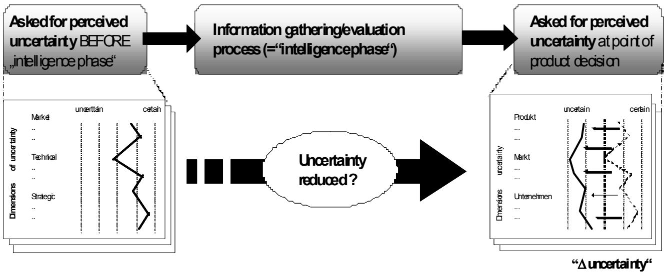
13 See Simon (1977)

14 See e.g. the phase models of decision making of Simon (1977) or Niggemann (1973)

15 In this context we understand "product decision" as the first (resource affecting) go/no-go decision to start the realization of a product.

the "intelligence phase"[16] of project selection.

Since the main goal of this intelligence phase is to achieve the best possible reduction of uncertainty in the run-up to the product decision[17], we compare the (information) uncertainty before the evaluation and selection process with the uncertainty after the project decision and take "uncertainty delta" as a measurement for the decision (process) quality[18,19].



Source: own depiction.

Fig. 2. Measurement of "delta in (perceived) uncertainty" as success variable for "intelligence phase".

Definition of (Un-)certainty

If we define the success of the intelligence phase as the reduction of uncertainty we also have to define uncertainty itself. According to Wittmann (1959), Duncan (1972), Milliken (1987), Schrader (1993) uncertainty exists if the decision maker disposes of less information than he needs to manage his task According to this definition certainty (as counterpart to uncertainty)[20] can be described as relation of information disposability and information necessity (importance).

Furthermore, according to many other authors, e.g. Downey and Slocum (1975), we consider information certainty (and thus also uncertainty) as subject to the perception of the decision maker and therefore perceptually based.

Accordingly we define the degree of certainty as the ratio between actually information disposable and information perceived as necessary.

$$\text{Degree of certainty} = \frac{\text{Information actually disposable}}{\text{Information perceived as necessary}}$$

Fig. 3. Definition of certainty

In this context we use the term "information" in a wider sense[21], e.g. ontologically as well as nomologically[22], i.e. not only knowledge of "facts and figures" but also knowledge of causal relationships.

Applying this definition to the FFE of innovation process we argue that uncertainty exists, if the known information about e.g. number of potential competitors in this market, the effect of this competitive environment on the company and the competitors' answers to the own market entry is minor than the (perceived) necessary information on these fields in order to make a correct decision.

3. Results

I. Which information and related uncertainties are crucial for the product selection decision to the R&D decision makers?

Lynn and Akgün (1998) argue that uncertainty within R&D project selection manifests itself in two primary forms: market and technical. Already in Ansoff´s uncertainty matrix[23], these two dimensions of uncertainty are the most relevant. And according to Calantone et al. (2003) a turbulent environment is one in which frequent and unpredictable market and/or technological changes within an industry accentuate risk and uncertainty in the NPD planning process.

While technical uncertainty is typically determined by the questions if, how, and with which technical effort the innovation can be realized, high market uncertainty is characterized by a lack of certainty who the future customers are and what they prefer (Jaworski and Kohli, 1993). In this context companies typically struggle with questions such as: What is the target market? What is the size of this market? What prices are customers willing to pay? What in essence do customers really want? And when do they want it (Lynn and Akgün, 1998).

Nevertheless, there are other potential dimensions of uncertainty than market and technical uncertainty. At least strategic uncertainty, i.e. the uncertainty about long term implications for the company, and resource uncertainty like uncertainties regarding human and financial resources to manage the task[24], must be

16 As described before, the expression "intelligence phase" originates from planning and decision theory and was established by Simon (1977).

17 See Schrader, Riggs and Smith (1993) and Courtney (1997)

18 This measurement for decision quality, i.e. the difference in uncertainty between these two points in time, avoids the time-lag problem between product decision and product success as good as possible.

19 Verworn (2005) found out that uncertainty reduction (within FFE) itself has an direct and indirect effect on overall product success.

20 Sauter (1978) describes uncertainty as the absence of certainty.

21 According to Lawrence and Lorsch (1967) uncertainty concerning sub-environments, e.g. sales, production, and R&D, consists of three elements: lack of clarity of information, general uncertainty of causal relationships and time span of feedback about results.

22 See Gäfgen (1968)

23 See Ansoff (1988)

24 In this context we consider "organizational uncertainty", i.e.

mentioned as additional uncertainties in the context of NPD. Mullins and Sutherland (1998) state that NPD managers must cope with uncertainty regarding their customers' needs, uncertainty as to which are the best long-term technology and market paths to follow, and uncertainty over the levels of resources to commit to achieve success.

In order to understand the level of uncertainty R&D managers are facing, they were asked for the perceived uncertainty on different relevant items. They stated their (perceived) information status (disposability) on a likert scale from 1 to 7 – before and after the intelligence phase. Furthermore we asked them for the (perceived) necessity of this information for their decision (on the same scale).

The information perceived as to be the most important from the perspective of R&D managers concerning the project selection process[25] are shown in fig. 4:

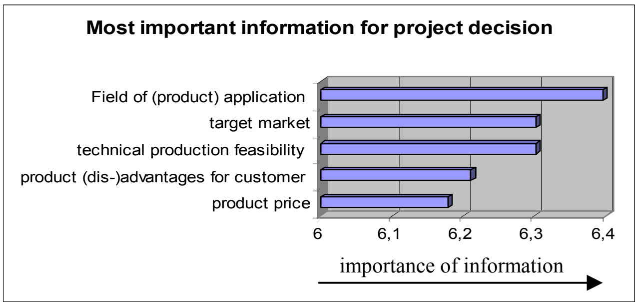


Fig. 4. Most important information for project decision (N=96).

As described above, the R&D managers were asked not only to state the importance but also the actual information status on same items at two points in time: before the start of intelligence phase and after the project decision.

Based on the definition of certainty described in fig. 3, we calculated the perceived uncertainty in the relevant item. Most uncertain information items before intelligence phase are shown in fig. 5:

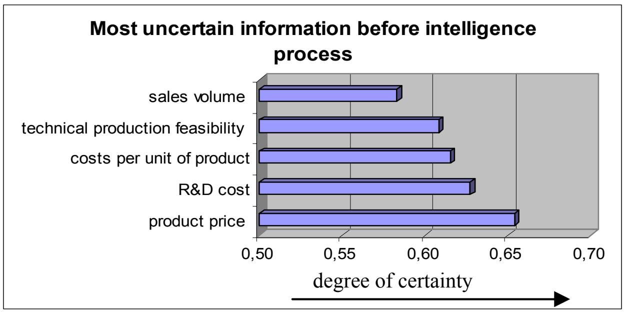


Fig. 5. Most uncertain information before intelligence process (N=94).

With regard to our first research question we can say that certainty about the field of product application, the target market and the production feasibility are the most important criteria for initial product decision (see fig. 4).

As fig. 5 shows, on average, uncertainties before intelligence phase are highest in the fields of future sales markets (volume and price), production feasibility (including related R&D effort) as well as product cost related uncertainties (e.g. cost per unit). They are only reduced by minor degree before project approval for development or its termination.

Different uncertainty profiles

Moreover, we wanted to find out if different uncertainty profiles among the companies exist. For this purpose we carried out a cluster analysis using the different degrees of uncertainty in the various uncertainty dimensions.

The following results of the cluster analysis indicate that there are five different uncertainty clusters of companies within our sample.

Cluster No.	Characteristics / Title (acc. to factor components)	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Total share (N= 96)	Technological newness of product	Market newness of product
1	"Certain in most dimensions"	0.75	0.62	0.44	-0.08	0.12	0.33	23.9 %	-0.13	-0.2
2a	"Uncertain in most dimensions"	-0.37	-0.53	-0.62	0.14	-0.09	-0.01	26.0 %	0.27	0.29
2b	"Uncertain in all dimensions but technical"	**1.23**	-0.14	-0.83	-0.51	-0.06	-0.53	11.5 %	-0.70	0.13
3	"Strategically uncertain"	0.58	**-1.51**	0.88	0.27	0.19	-0.10	11.5 %	-0.11	0.07
4	"Technical uncertain"	**-1.07**	0.66	0.19	0.04	-0.08	-0.02	27.1 %	0.20	-0.18

Table 1. Cluster of (un-)certainty profiles of companies within sample.[26]

The clusters are described by differently distinctive uncertainty dimensions which we found out by a factor analysis. This factor analysis was based on 20 single information items which were mentioned most frequently in the explorative expert interviews and related research as well as relevant management literature[27]. We can distinguish between six dimensions of (un-)certainty[28]:

Factor 1: Technical feasibility related uncertainty (incl.
related R&D effort)
Factor 2: Strategic uncertainty
Factor 3: Sales market uncertainty
Factor 4: Internal resources uncertainty

the uncertainty, if the organizational boundaries fulfil the requirements of the innovation task, as a part of the "resource uncertainty".

25 R&D managers were asked to rate the importance of 20 information items for the product decision on a scale between 1 (=not important at all) and 7 (=very important).

26 All factor values are standardized, i.e. mean=0; standard deviation=1.

27 See e.g. Souder and Moenaert (1992), Lynn and Akgün (1998), Cooper (1992)

28 As extraction method we used the principal component analysis, as rotation method we used Varimax method with Kaiser normalization (rotation converged in 5 iterations). The number of factors was determined by Kaiser criterion, i.e. the Eigenvalue of all extracted factor is > 1 (see Backhaus et al., 2003). For rotated component matrix see appendix: table 2.

Factor 5: Field of (product) application uncertainty
Factor 6: Environmental (competitive and legal) uncertainty

The total variance explained by these six factors is 67,6%.

As the cluster analysis shows, different profiles of uncertainty exist when the evaluation and selection process within NPD in automotive supplier industry is organized:

Only 23.9% of the companies in our sample are certain in most dimensions before they start the intelligence phase in order to make the right project selection decision (see table 1: cluster 1). This is mostly the case if the innovation is not a technical challenge for the supplier and the OEM already has agreed on volume and price. In most of these cases the R&D risk is carried by the OEM or at least shared between supplier and OEM.

Many R&D managers perceive uncertainty in most dimensions (see table 1: cluster 2a and 2b, which sum up to 37.5%) and only in about one third of these cases they feel quite safe concerning the technical dimension, potentially because the degree of technical newness of the innovation is not that high and/or the knowledge in this field is already established.

Finally, we identified two further clusters, each about a quarter of the sample, in which R&D managers felt uncertain about either strategic aspects (i.e. long term implications on the company´s brand, other products or future technologies) or the technical dimension (mainly as consequence of technical newness or missing fit with the company´s knowledge resources.

We assume that uncertainty is not only contingent upon organization-inherent factors (e.g. know-how within the company) but also upon specific characteristics of the project, especially the degree of "newness" or "innovativeness"[29]. Although it is explicitly not a key target of this paper to evaluate detailed causes for uncertainty, we asked the respondents of our survey for the degree of newness in terms of both technological and market aspects of the innovation project (as potential indicators for "project inherent uncertainty") to compare the results with our uncertainty clusters (see table 1: right colums).

Results show that in clusters with high uncertainty, the degree of product newness[30] is above average (see table 1: clusters 2a, 2b and 4) but less significant than expected.

Obviously the influence of the product newness on (perceived) uncertainty is limited. In fact, company-inherent factors (e.g. knowledge resources, the company´s innovation culture), external factors (e.g. competitive environment, legal/regulatory aspects), and other factors describing the specific uncertainty situation (as well as the company´s fit to this situation) influence the perceived uncertainty. These factors will be subject of further research.

II. How do R&D decision makers today cope with typical challenges related to reducing uncertainty? Where do they face major problems and how effective are they?

Regarding such significant differences in uncertainty profiles before the project decision, we can also expect different approaches in handling these uncertainties with regard to the project selection process. Thus, the overall innovation strategy applied should reflect the uncertainty situation of the company.

General innovation strategies and their implications for the project selection approach

Lynn and Akgün (1998) suggest six general innovation strategies/approaches to cope with a dynamic, uncertain environment: market-, technology-, speed-, learning-, quantitative-, and process- based approach.

Market-based innovation strategies regard the customer as focal point of all innovation efforts, i.e. communication with the customer is most important at all stages of the NPD process including the FFE (see e.g. von Hippel, 1986). Consequently, the customer probably should also be involved in the project selection phase. Other authors felt that especially at the early stages and especially in cases of radical innovations and discontinuous situations the involvement of customers has no effect or even is counterproductive and can lead to failure of the project (e.g. Lawtoon and Parasurama, 1980 or Christensen and Bower, 1996).

In contrast to market-based innovation strategies (also called "technology-pull-strategies") the *technology-based strategies* focus on R&D departments or engineering groups as sources of innovation ("technology-push"). The customer plays (if at all) only a minor role – especially at the front end of innovation. Project selection decisions are dominated by the engineering competencies within the company.

Takuchi and Nonaka (1986) propose a *speed-based innovation strategy* which underscores speed and thus flexibility as essential for coping with uncertainty and therefore product success. This includes e.g. simplified development, eliminated delays, speed-up operations, and parallel processing. Applying this to the FFE, the company would probably prefer R&D projects which are flexible to change and/or an innovation system in which the main focus is not on project selection at all but on high flexibility during execution (e.g. the flexibility to change the product selection decisions more often).

Learning-based strategies are characterized by long periods of research, development, and problem solving. Experimenting thus is an essential part of this approach. Many authors, e.g. Meyers and Wilemon (1989) or Nonaka (1990), assert that companies should enhance their ability to create, store and retrieve learnings across the NPD and embody them in new technologies and

29 According Herstatt, Verworn and Nagahira (2006) the more radical the innovation project, the more difficult an early assessment of an idea becomes.

30 The two factors "technological newness" and "market newness" of a product were extracted by a factor analysis. Factor values are standardized, i.e. mean=0; standard deviation=1.

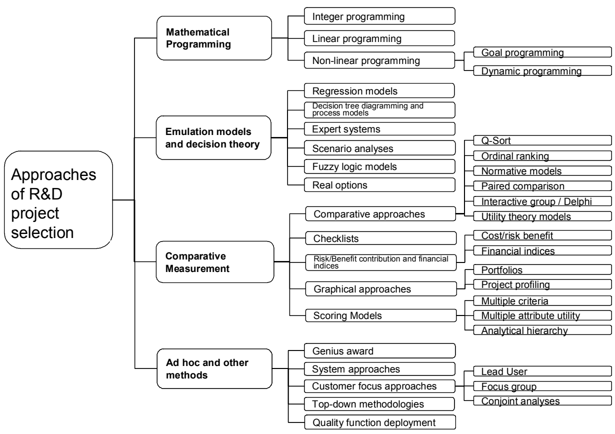
products. This strategy would prefer fields of innovation where expertise either already exists or easily can be established – or projects where time is not a critical issue.

The object of the *quantitative-based approach* is to determine metrics to assess and evaluate projects (Lynn and Akgün, 1998). It includes both financial and marketing metrics, e.g. the net present value (NPV), the return on investment (ROI), market share and sales volume (Mahajan and Wind, 1992).

The *process approach* is best described by Cooper´s multi-phase NPD approach ("stage-gate-process") whereof some stages have been identified as especially critical. Cooper and Kleinschmidt (1986) emphasize the importance of the early process stages and therefore suggest e.g. early market studies, intensive initial screening, and preliminary market assessment.[31]

Uncertainty reduction and project selection practice

Based on the rich body of project selection literature we classified the R&D project selection methods and tools in accordance with Hall and Nauda (1990) along four major categories (see fig. 6):



Source: Hall and Nauda (1990), modified by the authors.

Fig. 6. Over view of R&D project selection methods and tools.

In order to find out, how effectively the companies reduce uncertainty in the run-up to the product decision with (or without) help of these R&D selection methods and tools, we asked them again to assess the information status (immediately) at the point of the product decision (i.e. after the intelligence phase).

The results suggest that the intelligence phase on our certainty scale in average results in an increase of certainty by 0.15 (from 0.74 to 0.89). Nevertheless, a comparison with the most uncertain information before the intelligence phase shows that uncertainties have been reduced to different degrees.

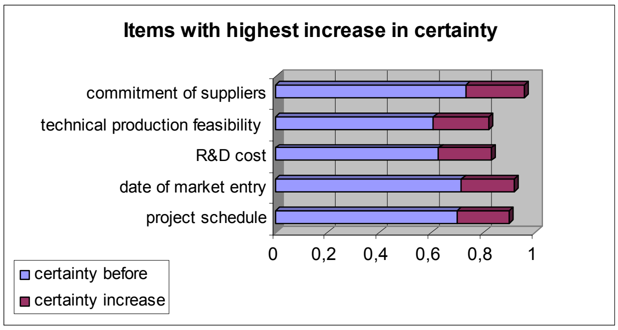


Fig. 7. Items with highest uncertainty reduction (=increase in certainty) within intelligence phase (N=96).

Uncertainty reduction (i.e. highest increase in certainty) was most successful regarding the items shown in fig. 7.

Accordingly, least uncertainty reduction was achieved in the items shown in fig. 8:

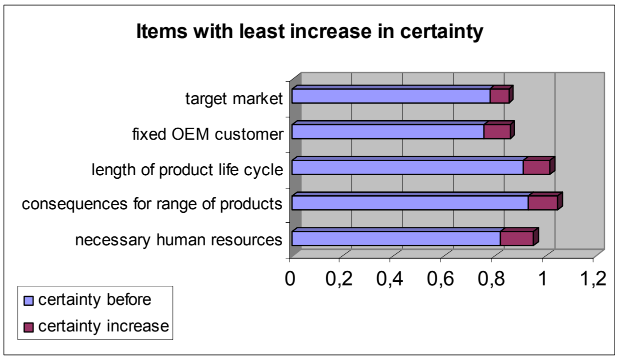


Fig. 8. Items with least uncertainty reduction (increase in certainty) within intelligence phase (N=96).

The results show further that even if some uncertainties are reduced only by a minor degree, it is possible that (after the intelligence phase) more information is disposable than necessary to make the right decision. An example for this is the information item "consequences for range of products". The average information disposable (e.g. achieved by a product-mix analysis) on this item at the end of the intelligence phase is greater than the information perceived necessary (in order to decide). Since we define uncertainty as ratio of these two values uncertainty measurement becomes greater than 1 (see fig. 8).

In these cases the resources for the intelligence phase probably have not been allocated efficiently because the additional information in this field is of no (additional) use.

As described above, the target of the intelligence phase is to make the gap between information disposable and information necessary as small as possible or reduce it to zero. Of course, this might not always possible or economical reasonable.

The fields of uncertainty with the highest remaining gap are shown in fig. 9:

[31] Although we focus in this study on the initial screening of potential innovation projects and therefore mostly on Cooper´s process strategy, some of project selection methods which literature offers can also be allocated to other strategies, e.g. the market- and quantitative-based strategy.

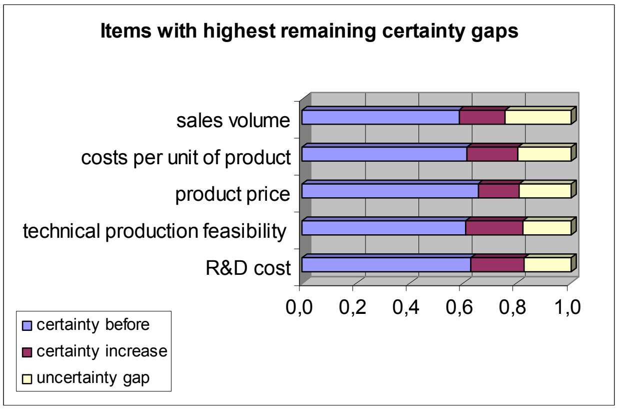


Fig. 9. Items with highest remaining certainty gap (N=96).

But our study not only shows differences in uncertainty reduction between the categories but also between the companies.

In general we found that existing NPD tools or market research activities described in the academic literature, like scenario analyses, conjoint analyses, focus groups, lead user method or even more sophisticated tools from utility theory, e.g. MAUT[32], only play a minor (or ex-post justifying role) in practice – at least in the FFE. Especially the relatively low efforts regarding market research activities within the intelligence phase, i.e. before the product decision, were astonishing[33]. A possible explanation for this might be the fact that a certain amount of innovation projects are initiated (and at least partially financed) by an OEM which will become customer and thus ensures a certain sales volume of the product. Of course, this significantly reduces market related uncertainties and accordingly the need for market research activities.

Success factors of uncertainty reduction

As we already demonstrated above, results show that different uncertainty profiles of companies can be distinguished. The same is true for the strategies of handling these uncertainties, where we also found different dimensions.

We classified the different decision and selection approaches within the companies not only by asking about the tools and concepts (see fig. 6) which were used for selection but about the more general (characteristic) "guiding principles" of the selection/decision process. We used 18 items which we reduced to six distinguishing dimensions by a factor analysis[34].

32 MAUT = multi attribute utility theory

33 Only 30.2% of the responders stated that comprehensive market research activities had been carried out (before product decision) and just 20.8% stated that the results of these activities had a significant influence on the product decision.

34 As extraction method we used the principal component analysis, as rotation method we used Varimax method with Kaiser normalization (rotation converged in 9 iterations). The number of factors was determined by Kaiser criterion, i.e. the Eigenvalue of all extracted factor is > 1 (see Backhaus et al., 2003). For rotated component matrix see appendix: table 3.

According to their component matrix we labelled them:

1. degree of quantitative/objective (vs. qualitative/intuitive) decision making
2. degree of customer integration
3. degree of internal (vs. external) information sources
4. degree of simulation technique use
5. degree of market research use
6. degree of strategic fit

The total variance explained by these six factors is 70.2%.

Whereas some companies manage to reduce uncertainties effectively before the final product decision, others do not manage this effectively at all (or even do not care at all). To investigate this in more detail we compare the most effective third with the least effective third within our sample in terms of uncertainty reduction in the six dimensions above.

In this context we regard the intelligence phase of a company as effective if on average (a) it achieves a high (relative) increase in certainty and (b) it achieves a high (relative) reduction of the (remaining) uncertainty gap. We combined these two criteria[35] to avoid that companies with high uncertainty reduction but still high (remaining) uncertainty gap (a but not b) or companies with small remaining uncertainty gap but minor uncertainty reduction (b but not a)[36] are counted as effective in uncertainty reduction.

With help of a discriminant analysis we found out that the group of the most effective intelligence group significantly differs from the least effective cases regarding the degree of strategic fit within their project selection practice, i.e. the selection process of the successful companies is more guided by the strategic vision of their own company and their (potential) customers.

This result seems to be independent of the degree of product newness. The discriminant analysis shows that neither market nor technical newness of a product significantly differs between both groups, i.e. the average degree of product newness in both group is rather similar.

Moreover, there are minor differences in use of external (vs. internal) information sources and degree of customer integration in the project selection process. Values for both dimensions are slighty higher in the effective intelligence group.

In answer to our second research question it can be said that especially market and cost related uncertainties (e.g. sales volume, product price, cost per unit) are only reduced by a minor degree before the first resource affecting go/no-go product decision[37], whereas in other

35 As measurement for a combined success variable we multiplied both single uncertainty reduction measurements with each other.

36 This is e.g. the case if a high certainty base level exists.

37 See fig. 11

dimensions such as supplier commitment, environmental aspects, and field of product application, the task of the uncertainty reduction has been carried out very effectively or even "over-fulfilled" in terms of information accumulation.

Especially in innovation product decisions with high uncertainty a strong emphasis on the strategic fit (of the product decision) with own and the OEM´s strategy (e.g. "brand-fit") might be helpful in order to successfully reduce the uncertainty.

The knowledge about and especially the use of methods and tools differ between the group with effective uncertainty reduction and the less effective group: While use of methods and tools within the latter group seems to be rather limited to ad-hoc instruments and benefit measurement approaches, e.g. simple financial indices, the spectrum of methods used within the first group is broader and varies from scoring and portfolio models to financial indices, roadmapping, and simulation techniques.

Nevertheless, in both groups the majority of respondents states that they came to their final product decision more intuitively than "by mathematical calculation".[38]

Furthermore, the use of methods and tools seems to be independent from the degree of product newness – at least we did not found a significant correlation. This also implies that the selection of methods generally is not contingent upon the specific uncertainty profile of the company and the degree of product innovativeness.

Another noteworthy result is the discrepancy in resource availability during the intelligence phase in terms of personnel, financial, know-how, market research etc. resources. We found significant differences between the two groups in all resource dimensions.[39] More generally speaking, this lack of methodological knowledge as well as financial resources at this early investigative stage of decision process might even be an explanation for the striking discrepancy between the richness of existing NPD tools in academic literature and its scarce practical use within the companies.

4. Conclusions

What are major implications for managing the FFE of innovation process in industry practice and respectively for further academic research in this field?

There are some more general as well as some more specific recommendations for the project selection practice in automotive supplier industry resulting from our study: Firstly, the phase of information gathering and project evaluation within the FFE of the NPD process (which we called intelligence phase) should be better adjusted to the specific uncertainty situation. In order to achieve this, the supplier company should first analyze, to which uncertainty cluster the product decision fits best in the current state and which strategy (and –if applicable– related set of methods and tools) seems to be most useful to reduce uncertainty – based on available information and a best effort approach.

Secondly, companies should ensure to have sufficient resources available in terms of personnel (know-how) and financial means (e.g. for market research activities) to be used for the purpose of project selection.

They should further acquire a "basic set" of evaluation and selection methodologies and – most important – they should systematically apply them. For this purpose the transfer from academia to industrial practice must be enhanced, which is indicated by the still high discrepancy between methodologies available in theory and used in practice. The high resonance to our study by the R&D managers of many automotive supplier companies may indicate a general willingness for this.

For academia this primarily means that the assessment of successful FFE project selection practices is still an important topic and not easy to measure. Referring to decision theory, the "uncertainty gap" (respectively its reduction during intelligence phase) may be one helpful and valid success measurement for this phase.

It is still not sufficiently investigated what selection and evaluation approach fits best to which uncertainty situation and by which factors it is influenced (e.g. industry characteristics, company environment or even specific uncertainty situation etc.).

Another interesting aspect evolving from our results is the question, how a more strategy-oriented innovation selection approach (e.g. fit with own and OEM´s branding and/or production strategy) could reduce uncertainty within the innovation process, respectively the FFE.

Limitations

Since we focused in our study on the German automotive supplier industry this research and hence implications drawn from it are to be seen with regard to this industry.

We furthermore point out the well-known limitations regarding ex-post-measurement, a possible bias related to single-informant approach, and general methodological-inherent limitations of the multivariate analyzing methods (factor analysis, cluster analysis, and discriminant analysis) we used in our study.

38 In the group with effective uncertainty reduction the answers of 53.1% ranged within 1 to 3 on a likert-scale from 1 (=intuitive) to 7 (=mathematical), in the less effective group this value was even 81.3%.

39 Resource sufficiency stated within the group of more effective uncertainty reduction was in average 1.6 points higher than in the other group (on a likert-scale from 1=resources completely sufficient and 7=resources not sufficient at all), in the dimension "market research resources" the difference was 2.3 points.

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APPENDIX: COMPONENT MATRICES OF FACTOR ANALYSES

Rotated Component Matrix	Factor					
Item of information certainty[40]	1	2	3	4	5	6
Production feasibility	**0.82**	-0.05	-0.08	0.04	0.01	0.19
Project schedule	**0.63**	-0.02	-0.17	0.33	-0.3	0.15
Product unit cost	**0.88**	0.07	0.08	0.01	0.03	-0.04
R&D cost	**0.87**	0.00	0.03	0.08	0.04	0.03
Suppliers (for production phase)	**0.75**	0.01	0.00	-0.19	0.09	-0.18
(Length of) product life cycle	-0.04	**0.85**	0.06	0.04	-0.03	-0.04
Potential future competitive technologies	-0.14	**0.72**	0.09	-0.12	0.16	-0.07
Consequences for range of products	0.06	**0.79**	0.02	0.11	-0.03	0.26
(Other) strategic consequences for own company	0.15	**0.74**	0.06	0.01	0.09	0.22
Target market	-0.08	-0.02	**0.78**	-0.04	-0.02	-0.03
Concrete OEMs as customers	-0.09	0.04	**0.83**	0.06	0.05	-0.04
Sales volume within first 2-3 years	0.02	0.21	**0.83**	-0.03	-0.05	0.05
Sales price within first 2-3 years	0.10	0.02	**0.64**	0.03	0.03	0.26
Securing necessary financial resources for project	0.05	0.02	0.01	**0.92**	-0.04	-0.02
Securing necessary personnel resources for project	0.01	0.01	0.03	**0.88**	0.14	0.01
Field(s) of product application	0.12	0.05	-0.11	0.02	**0.82**	0.07
(Dis-)advantages (of product) for customer	0.10	0.19	0.07	0.16	**0.68**	0.12
Competitive environment	-0.02	0.23	0.15	0.03	0.00	**0.75**
Public/legal environment	0.06	0.03	0.02	-0.03	0.07	**0.84**
Date of product launch	0.37	0.11	-0.05	0.1	**0.59**	0.14

Table 2. Rotated component matrix of factor analysis: Dimensions of uncertainty[41]

Rotated Component Matrix	Factor

[40] Item titles are translated and partially abbreviated.
[41] Extraction method: principal component analysis; rotation method: Varimax with Kaiser normalization (rotation converged in 5 iterations)

Item (statement) with regard to project selection process[42]	1	2	3	4	5	6
A fixed and documented evaluation process was conducted.	**0.72**	-0.05	-0.18	0.16	0.31	0.20
Fact/figure driven methods were predominant.	**0.77**	0.10	0.10	0.18	0.09	-0.10
Qualitative aspects were dominating the project selection process.	**-0.69**	-0.09	-0.01	-0.12	0.18	0.32
The project selection decision was based rather on "mathematical calculation" than on intuition.	**0.75**	-0.04	-0.19	-0.08	0.11	0.38
Personal beliefs of single stakeholders played an important role.	**-0.80**	0.10	0.21	0.05	-0.24	-0.16
The importance of objective evaluation criteria used in selection process was rather low.	**-0.76**	0.07	-0.17	0.02	-0.06	-0.01
Before project decision comprehensive interviews with potential customers (OEMs) have been conducted.	-0.02	**0.78**	0.08	0.09	0.25	0.13
Before project decision comprehensive interviews with potential end users (drivers) have been conducted.	-0.07	**0.85**	-0.18	0.03	-0.09	0.15
The project decision was mainly based upon (company) internal knowledge and experiences.	0.07	-0.09	**0.87**	-0.08	-0.20	0.19
Information for project decision was primarily acquired from external sources.	0.11	0.09	**-0.69**	0.05	0.25	-0.48
The market research activities have been predominantly conducted by an internal market research department	0.09	0.08	**0.66**	0.18	0.36	-0.34
A comprehensive "technological forecasting" was used to assess technological trends.	0.14	0.17	0.13	**0.72**	0.24	0.09
Simulation techniques were intensively used in order to assess technical feasibility of the project.	-0.15	-0.17	0.00	**0.79**	-0.08	0.04
Simulation techniques were intensively used in order to assess market potential of the project.	0.30	0.23	-0.16	**0.74**	0.03	-0.05
Comprehensive market research analyses have been conducted before project decision.	0.19	0.01	-0.13	0.03	**0.82**	0.06
The result of market research analyses significantly influenced the project decision.	0.10	0.15	-0.02	0.08	**0.88**	0.09
The innovation perfectly fits into the product/brand strategy of at least one potential customer (OEM).	0.12	0.32	0.07	0.11	0.18	**0.61**
The innovation perfectly fits into the own product/brand strategy	0.04	0.09	0.09	0.03	0.04	**0.68**

Table 3. Rotated component matrix of factor analysis: "guiding principles" of project selection process[43]

[42] Item titles are translated and abbreviated.
[43] Extraction method: principal component analysis; rotation method: Varimax with Kaiser normalization (rotation converged in 9 iterations)