MASTER

Real options strategy as formative or reflective second-order construct?

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Real Options Strategy as formative or reflective second-order construct?

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Abstract

Introduction

Despite intensive discussions about real options strategy, little research addresses how to model real options strategy in a new technology venture. Recent literature proposes various concepts of real options strategy but does not feature an empirical study that identifies and quantifies the different dimensions of this construct. In the current study, the author develops a formative measurement model for real options strategy as a second-order construct that indicates what dimensions of real options strategy are needed to be considered. The study presents a complete process for conceptualizing and operationalizing a formative second-order construct, including a thorough literature review and a quantitative study with 123 new technology ventures. On the basis of this process, the author models real options strategy as a function of three dimensions, option to defer/learn option to grow/invest, and the option to disinvest/shrink. The resulting formative operationalization satisfies the criteria for evaluating formative indexes. This report concerns a study on how to model the construct real options strategy and its dimensions.

Literature review

In current business environment where uncertainty and rapid changing circumstances are a central difficulty in investment decision-making, the need to reconsider traditional instruments to evaluate investment decisions is increasing (Sadowski, 2007). The recently emerged real options strategy (McGrath, 1999) is one of the latest strategies that incorporates flexibility to make investment decisions (Podoynitsyna, 2008).

Generally, technology managers are always making two-sided choices. On the one hand, they have to make early investment decisions in order to adapt to the need for increasing speed to the market. Often, investment decisions are irreversible and the money can be spent once. Therefore, on the other hand, sometimes it is better to wait with a decision to invest. This brings up the main concept in this paper, the real options strategy.

Real options strategy is a firm's strategy to manage risk and uncertainty by pursuing multiple product options with high growth potential and high uncertainty, while further investments into a product option are only made if uncertainty has been resolved and conditions are favorable (McGrath, 1999).

In general, the core idea of a real option is that a limited commitment will be made that creates future decision rights (McGrath et al, 2004). In recent years, the concept of real options has created considerable excitement in management literature. In studies, several classifications are introduced (see e.g. Copeland and Keenan, 1998; Huchzermeier and Loch, 2001). For example, Huchzermeier and Loch (2001) present real options strategy as a construct that consists of four different types of options, namely the defer option, the abandonment option, the expansion option, and the switching option. Contrary, Copeland and Keenan (1998) divide the construct real options strategy into three different dimensions, the option to invest or grow, the option to defer or learn, and the option to disinvest or shrink. This shows that several classifications exist and no universal way to classify real options exists.

However, only conceptual works apply to the design of a way to model the construct real options strategy (Brosch, 2001; Bräutigam et al., 2009; Copeland and Keenan, 1998; Podoynitsyna, 2008), a lack of empirical research pertains to real options strategy, and no clear evidence describes which dimensions are needed to be considered. Yet developing a measure of real options strategy would help identify and quantify those dimensions that constitute systematic real options strategy. Such a measure further would demonstrate how real options strategy is build up

and therefore existing knowledge about the dimensions of real options strategy will be increased. In turn, this information could enable new technology ventures to regard which dimensions are important. Against this background, this research conceptualizes and operationalizes a measure for real options strategy as companies apply the concept. The author identifies and measures a set of real options strategy dimensions that together define real options strategy.

Research questions

A general research question is stated, namely:

What is an appropriate way to present the concept of real options strategy in new technology ventures?

This question is divided into four sub questions. The first question evaluates different classifications of option types presented in literature. The second question focuses on the extent that the different option types are correlated to each other in new technology ventures. The third question focuses on the question whether to model the construct real options strategy in a formative or reflective way. The fourth question relates to the influence of the different types of real options on a new technology venture's performance.

Methodology

The study took place in cooperation with dr. J.D. van der Bij and dr. K.S. Podoynitsyna, both members of the School of Industrial Engineering of the Eindhoven University of Technology.

In this study, we can make use of a database based on a survey (Appendix A) that is used in a study of Podoynitsyna (2008). The sample frame was consisted of 11,029 venture-backed young technology firms in the VentureOne 2001 database and 982 new technology venture firms who were members of the 1995-2000 *Inc 500* (this is a listing of the fastest growing private companies in the United States, as selected by Inc magazine). As mentioned in Podoynitsyna (2008), 2,000 new technology ventures were randomly selected for the survey. The first mailing packet included a project fact sheet, a personal letter, the survey, a priority postage-paid envelope with an individually-typed return address label, and a list of research reports available to participants. Due to some undelivered mail addresses the adjusted samples consisted of 1,431 new technology ventures. With follow-up mailings and letters, the response rate was tried to be increased. After these efforts, a response rate of 420 firms was achieved. In this research, we only use the abovementioned cases of the database.

Based on the framework of Coltman et al. (2008), the author is helped with designing and validating the proposed models. Three theoretical issues and three empirical considerations are taken into account. This framework consists of regarding the nature of the construct, the direction of causality, characteristics of indicators, item intercorrelation, item relationships, and the analysis of measurement error and collinearity.

Results

To classify specific dimensions of real options strategy, this research conceived real options strategy as a second-order construct that consists of first-order dimensions, which themselves consist of specific indicators. These dimensions contribute to the overall real options strategy construct. Therefore, as this report shows subsequently, a formative measurement approach is appropriate. In our most valid model, the classification of Copeland and Keenan (1998) is used for presenting the construct real options strategy in an appropriate way. Factor correlation in this context is hard to judge, but it seems that some correlation among different options exists. Furthermore, in the context of this special issue, this research offers directions regarding how to operationalize second-order constructs using formative indicators. Finally, the influence of real options strategy on a new technology venture's performance is investigated. On the one hand, empirical analysis shows that it is hard to make a definite judgement about this issue, but it is shown that some influence exists. On the other hand, literature shows that by encouraging managers to think of decisions as carrying with them embedded options, they can produce more effective strategies and achieve a higher performance.

Conclusion

This study provides insights in real options strategy as a second-order construct. Results show that this construct can best be modeled in a formative way. Empirically this was hard to judge, but based on literature a sound consideration is made. Furthermore, results show that it can be suggested that some factor correlation exists. Finally, the influence of the different real option types on a new technology venture seems to exist.

Overall, the concept of real options strategy that this research presents offers an important foundation for the implementation of real options strategy in practice, as well as for further research in this field. Consequently, this study represents a next step in the path, moving to a more empirical approach of investigating the construct of real options strategy.

Preface

I conducted this study in partial fulfilment of my Master of Science degree in innovation management. It was executed under supervision of the School of Industrial Engineering of the Eindhoven University of Technology and regards a project conducted within the group of Innovation, Technology Entrepreneurship, and Marketing that focuses on new product development processes and is a leading group in innovation management in Europe.

I would like to express my gratitude for the support and feedback I received from my university mentors, Hans van der Bij and Ksenia Podoynitsyna. Furthermore, I would like to thank all new technology ventures incorporated in this study that made it possible to gather the data. Without them, this thesis would not have been realized. Finally, I would like to thank all others that provided me with support, input, or feedback over the course of my master thesis project.

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1 Introduction

Real options strategy refers to a firm's strategy to manage risks by pursuing multiple product options with high growth potential and high uncertainty, while further investments into product options are only made if uncertainty has been resolved (McGrath, 1999; McGrath et al., 2004; Podoynitsyna, 2008). Within these product options different option types can be considered.
When executives create strategy, they project themselves and their organization into the future, creating a path from where they are now to where they want to be in some years down the road. Generally, in a highly competitive market, no one expects to formulate a detailed long-term plan and follow it mindless (Luehrman, 1998). As soon as executives start with the path, they begin to learn about business conditions, competitors, regulations, and so forth. Therefore, they need to respond flexibly to what they learn.
In this case, an option-based approach seems to be interesting and therefore the construct of real options strategy is central in this study. This study presents a complete process for conceptualizing and operationalizing the construct of real options strategy, including a thorough literature review and a quantitative study. The following paragraph will describe the research question and the structure of the report.

1.1 Research question

The previously conducted literature review reveals a substantial gap in literature regarding the construct of real options strategy. Recent literature proposes various concepts of real options strategy but does not feature an empirical study that identifies and quantifies the different dimensions of this construct. Gaining insight into the construct of real options strategy in new technology ventures in practice could provide more knowledge about how to conceptualize and operationalize the construct of real options strategy. In the conducted literature review, I have discussed the current state of academic literature on the topic of real options strategy. In addition, several research gaps are presented and based upon this the general research question in this study is the following:

What is an appropriate way to present the concept of real options strategy in new technology ventures?

Some sub questions will be defined further on. Next paragraph will describe the structure of this paper.

1.2 Structure of the paper

The remainder of this report is structured according to logical steps in which the research has been conducted. Resulting in the following report and research structure.
Chapter 2 will provide a brief overview of the literature study that formed the starting point of this research. In Chapter 3, this literature overview is followed by a more detailed description of the research design and its research questions.
Chapter 4 and 5 consist of the main part of this research, namely the explorative factor analysis and the confirmatory factor analysis and its results.
Discussion, research contributions, managerial implications, and limitations are presented in Chapter 6. Finally, references and appendices are presented.

2 Literature Review

In this chapter, a short overview will be given of interesting literature about the concept of real options strategy. We start with a paragraph about the background of real options strategy. Furthermore, an introduction to real options strategy is given and some articles with glosses will be presented. In addition to this introduction, a paragraph will focus on the categorization of real options. Subsequently, the findings about major issues concerning options portfolio is given. Finally, the gaps found in literature will be presented.

2.1 Background

In current business environment where uncertainty and rapid changing circumstances are a central difficulty in investment decision-making, the need to reconsider traditional instruments to evaluate investment decisions is increasing (Sadowski, 2007). The recently emerged real options strategy (McGrath, 1999) is one of the latest strategies that incorporates flexibility to make investment decisions (Podoynitsyna, 2008).

Generally, technology managers are always making two-sided choices. On the one hand, they have to make early investment decisions in order to adapt to the need for increasing speed to the market. Often, investment decisions are irreversible and the money can be spent once. Therefore, on the other hand, sometimes it is better to wait with a decision to invest. Considering this brings up the main concept in this paper, the real options strategy.

2.2 Real options strategy

As mentioned by Miller and Arikan (2004), real options strategy offers an alternative for traditional risk management. Traditional risk management strategies target risk and uncertainty mitigation by strategic avoidance, strategic imitation, strategic control, or strategic cooperation (Podoynitsyna, 2008). In contrast to these strategies, real options strategy is a firm's strategy to manage risk and uncertainty by pursuing multiple product options with high growth potential and high uncertainty, while further investments into a product option are only made if uncertainty has been resolved and conditions are favorable (McGrath, 1999).

Real options strategy preaches choosing new products with high revenue potential and inherent high payoffs uncertainty and is therefore most useful in cases of high technology or market uncertainty (Podoynitsyna, 2008). At the same time, this strategy is involved with waiting to fully invest until uncertainty is resolved. In addition, real options strategy allows the decisions to be made both before and after the uncertainty surrounding these decisions has been resolved (Huchzermeier and Loch, 2001). In this sense, real options strategy is stricter than traditional methods because it has an assumption of actions and decision making only after the uncertainties are resolved and the conditions seems favorable (Adner and Levinthal, 2004a; 2004b).

In general, the core idea of a real option is that a limited commitment will be made that creates future decision rights (McGrath et al., 2004). Real options involve rights to acquire or exchange the value of the underlying asset for a specified price (Trigeorgis, 1998). In this paper, the focus is on new technology ventures and they have one common characteristic. They have to develop at least one product with a considerable amount of R&D. In this case, the underlying assets are the new products of the venture.

In recent years, the concept of real options has created considerable excitement in management literature. Generally, the appeal of real options is quite natural. Companies face uncertain futures, and the investment opportunities they face are a function of their prior investment commitments (Adner and Levinthal, 2004a). At the surface level, the real options framework appears to precisely fit a companies' strategic challenges by linking current actions to uncertain futures. However, less obvious than the benefits offered by the real options approach, some limitations exist and these are presented by Adner and Levinthal (2004a) and will be discussed further on in this paper. The usage of the real options approach seems only appropriate if there is (Dixit and Pindyck, 1994):

- uncertainty regarding the outcome which can be limited by
- the managerial flexibility to take action during that
- totally or partially irreversible investment involving
- asymmetric payoffs.

In addition to these assumptions, Adner and Levinthal (2004a) expect the following issues for real options firms, relative to their traditional counterparts:

1. They abandon projects earlier
2. They have higher project abandonment rates
3. They have stricter action mandates for business units and project teams
4. They have formalized milestones and go/no-go procedures
5. They have incentive systems, organizational cultures, and allocation mechanism that are more tolerant of failure
6. They review procedures that are more sensitive to the presence of different incentives at different levels of organization.

Adner and Levinthal (2004a) believe that an understanding of a theory's boundaries serves to make it more powerful and more precise. They argue that the cause of options thinking is best served in considering the boundaries of the domain of applicability of the real options logic for business strategy. The boundaries of real options logic are hard to define and research needs to be done to extend the knowledge on this topic.
The following paragraph will go into detail about the possible classifications of real options.

2.3 Option categorizations

The principle of real options strategy and its underlying assumptions has been presented in the previous paragraph. Within the heuristic of real options strategy several types of options exist. In this paper, several classifications will be introduced (Huchzermeier and Loch, 2001; Sadowski 2007; Copeland and Keenan, 1998; Mauboussin, 1999; Brosch, 2001; Trigeorgis, 1998; Bruun and Bason, 2001; Amram and Kulatilaka, 1999b; Pleines, 2006). A common used classification is given by Huchzermeier and Loch (2001). This classification will be presented in table 2.1.

2.3.1 Classification by Huchzermeier and Loch (2001)

In this paragraph, the classification based on Huchzermeier and Loch (2001) will be presented. This is one of the main classifications presented in literature.

Defer option
The defer option refers to the possibility of waiting until more information has become available (Huchzermeier and Loch, 2001). As mentioned by Trigeorgis (1998), the defer option is

particularly valuable in resource extraction industries, farming, paper products, and real estate development, because of the high uncertainties and the long investment horizons. Generally, investments are spread out over time and this gives some space for delaying investments. The decision to delay an investment depends on the way uncertainty is developing. If uncertainty is resolved in a way that is detrimental to a project's economic viability, investments will not be done and expenditures will be saved. On the other hand, if uncertainty is resolved favorably, it may be profitable to accelerate the investment process to speed up project's cash flows (De Maesenaire, 2006).

Abandonment option
Closely related to the defer option, the abandonment option offers the possibility to make investments in stages, deciding at each stage, based on the newest information, whether to proceed further or to stop (Huchzermeier and Loch, 2001). This option prevents losing revenues by not having to close down a part of the plant and ending op with the optimal decision (Mun, 2002). Furthermore, in manufacturing projects in which there is an active second hand market for the capital equipment, these options are extremely common to use. The abandonment option limits the project downside exposure since the worst outcome is the project's salvage value (De Maesenaire, 2006).
In some instances, it seems more feasible to make use of a shutdown option instead of the abandonment of a project. Especially, in projects with high variable costs and temporarily low demands it can be healthy to shut down operations. For example, shut down a copper mine when demand for copper is low and variable costs are high. It is important to consider the possibility to restart operations again. In some instances, it will be impossible to start up in the future again. Here, you can think of a research laboratory engaged in developing drugs. Closing operation would mean losing scientists and this makes it impossible to restart operations (De Maeseanaire, 2006).

Expansion option
The expansion option or contraction option represents the possibility to adjust the scale of investment depending on whether market conditions turn out favorable or not. This option is used to alter the operating scale by adjusting its utilization of production facilities and resources. This option may also be of strategic importance, especially if it enables a firm to capitalize future growth opportunities. A typical growth option is when a relative small investment will be done in a new emerging market with an initial small demand. The growth option gives the opportunity to expand the size of the investment in this similar market when demand is rising. For example, when the firm buys vacant undeveloped land, or when it builds a small plant in a new geographic location to position itself to take advantage of a developing large market, it essentially installs an option for future growth (Trigeorgis, 1998). Generally, the growth option is particularly valuable in high-tech or emerging industries (De Maesenaire, 2006).

Switching option
The switching option allows changing the mode of operation of an asset, depending on factor prices (Huchzermeier and Loch, 2001). Here, a distinction can be made between input flexibility and output flexibility.
The option to change the input is typical used to take advantage of changing relative prices. Firms may pay for having the possibility to switch between various input technologies. Two different input flexibility options can be mentioned. First, the opportunity to choose ex-post the

low-cost input, for example switching between the coal or oil input of a plant. Second option arises when a firm has established plants on different locations. Now, management can decide to allocate (more) production to cheaper factories (De Maesenaire, 2006).
The option to switch between different outputs can be important when changing market circumstances exist. In response to these changing market circumstances, management is able to alter the output mix. The company holds implicit options on the relative prices of potential outputs. Especially, manufacturers in automobile and high-technology industries have focused on this source of flexibility (De Maesenaire, 2006). Conclusively, a switching option provides the right and ability, but not the obligation to switch among different sets of business operating conditions, including different technologies, markets, or products (Mun, 2002).

Type	**Description**
Defer option	possibility of waiting until more information has become available
Expansion option	possibility to adjust the scale of investment
Abandonment option	possibility to make the investment in stages, deciding at each stage whether to proceed or not
Switching option	allows changing the mode of operation

Table 2.1: Different options and their description (based on Huchzermeier and Loch, 2001)

In some cases, Huchzermeier and Loch present a fifth type of option, namely the improvement option. Executing this option is injecting additional resources to improve mean expected attainable capacity by one level, or cut redundant resources to bring down mean expected attainable capacity by one level (Chen and Tokinaga, 2004). Often, this option can be seen as example of an expansion option or switching option in which an investment will be done, we will not take into account this option type in this report.
The categorization presented by Huchzermeier and Loch (2001) is no universal way. Another useful classification is presented by Copeland and Keenan (1998). They present real options as classified into three main groups: invest/grow options, defer/learn options, and disinvest/shrink options. Here, a framework is proposed with the main dimensions growth, defer, and quit.

2.3.2 Classification by Copeland and Keenan (1998)

Copeland and Keenan (1998) classify individual real option types into growth/invest options (scaling up, switching up, or scoping up a project), deferral/learning options, and disinvest/shrink options (scaling down, switching down, or scoping down a project). These are presented in table 2.2. In general we will use the categorization of Copeland and Keenan in three classes.

Real Option Type	Real Option Subtype	Description
Invest/grow	Scale up	Early entrants can scale up later through cost-effective sequential investments as market grows
	Switch up	Speedy commitment to first generation of products or technology gives company preferential position to switch to next generation
	Scope up	Investment in proprietary assets in one industry enables company to enter another industry cost-effectively
Defer/learn	Study/start	Delay investment until more information or skills are acquired, wait some period before investing
Disinvest/shrink	Scale down	Shrink or shut down a project part way through if new information changes the expected payoffs
	Switch down	Switch to more cost-effective and flexible assets as new information is obtained
	Scope down	Limit the scope of (or abandon) operations in a related industry when there is no further potential in a business opportunity

Table 2.2: Different options and their description (based on Copeland and Keenan, 1998 and Mauboussin, 1999*)*

2.3.3 Other important Classifications

In literature, some other classifications of real option types are used. These will be described in this paragraph. The classifications of Trigeorgis (1998), Brosch (2001), Pleines (2006) will be described.

First, the classification by Trigeorgis (1998) and Brosch (2001) consists of seven types of real options. The option to defer investment enables management to defer investment for up to a year and benefit from the resolution of uncertainty about a variable. The time-to-build option enables staging of capital investment as a series of outlays over time. Third option, the option to expand, may be of strategic importance, especially if it enables the firm to capitalize on future growth opportunities. The option to contract may be particularly valuable in the case of new product introductions in uncertain markets. The option to shut down and restart operations speaks for itself. The option to abandon for salvage value gives the management the opportunity to abandon the project permanently in exchange for its salvage value. Finally, the option to switch gives the opportunity to switch the input or output of a project.

Second, the classification by Pleines (2006) distinguishes between six types of options. The option to grow gives the opportunity to invest in new projects or subsequent project stages. A growth option can be the development of a new product or any other activity that grants access to and establishes a company in new markets or market segments. The option to wait gives the opportunity to delay an investment. The option to change scope gives management the opportunity to adapt to changing market conditions. Fourth option type by Pleines (2006) is the option to exit. This type of option leaves management the opportunity to discontinue a project and sell the related assets. The option to switch can be described as the flexibility to alternate between different modes of operation. Switching can occur between production inputs and production outputs, between different production technologies or processes, or between manufacturing locations. Last option type of Pleines is the option to stage or learn. During each stage information about the outcome and the environment of the project are collected creating the opportunity to adjust the following stages to the new situation. This opportunity to continuously learn allows for better decision making during the course of a project (Pleines, 2006).

Several differences and similarities between the different classifications of option types can be presented. A general similarity is that all option types are in some part focused on a way of managerial flexibility. In other words, all option types involve a kind of choice.
Differences between option classifications exist in a couple of issues. There is a difference in the number of types of options an author handles. Some authors define seven different types of options (Trigeorgis, 1998; Brosch, 2001), while others divide the construct real options strategy in only three dimensions (Copeland and Keenan, 1998). Furthermore, a difference exist in the way how the option are categorized. Copeland and Keenan define their categorization in terms of investment decisions (to invest, to disinvest, or to wait to invest), while other authors present the dimensions of real options strategy more in terms of operational activities (Trigeorgis, 1998; Pleines, 2006). Finally, a difference exist in the use of real options strategy in a corporate company or a new technology venture. In new technology ventures, the option to exist seems not to exists because this can be seen as a form of suicide, while in corporate companies with several product options, this option can be useful when total disinvestment is necessary (Kortner, 2002).
In literature no consensus exists about the classification of real options. Several other categorizations are available in literature and it is not known whether these categorizations are valid or the best. Empirical research needs to be done to examine which categorization can be seen as appropriate.

2.4 A portfolio of real options

These paragraphs will go into detail about the aspects that are important concerning a portfolio of real options. First, a description is given of how real options are considered in this paper. Second, the first level of real options is described, namely the product options. Thirdly, a lower level, the options types are taken into account. Fourthly, a paragraph is focused on the way how a portfolio of real options can influence a company's strategy. The fifth paragraph will describe the way how real options in a portfolio can influence each other and possible interactions are taken into account. Finally, an illustrative example is given based on Luehrman (1998).

2.4.1 Real options defined

To be complete, we will summarize the definition of real options strategy as mentioned in paragraph 2.2. General, the core idea of a real option is that a limited commitment will be made that creates future decision rights (McGrath et al., 2004). It can be seen as the right, but not the obligation, to buy (or sell) an asset at some point within a predetermined period of time for a predetermined price (Copeland and Keenan, 1998). Real options involve rights to acquire or exchange the value of the underlying asset for a specified price (Trigeorgis, 1998). In this paper, the focus is on new technology ventures and they have one common characteristic; they have to develop at least one product with a considerable amount of R&D. Real options can be considered on two different levels, which will be described in the following paragraphs.

2.4.2 Product options

Generally, a new technology venture enters the market with only one new product. With introducing this first product, several other product opportunities arise. These product opportunities can be seen as the highest level of real options. Some product options are strongly related to the product already introduced, while other product options seem to have almost no relationship with the introduced product. The strongly related products are often variant types of one product. For example, the different product options are varying from product 1 to product X, with product 1 more related to product 2 than product 14 does. McGrath (1999) defined these product options as entrepreneurial initiatives, whose value is fundamentally influenced by uncertainty. These initiatives should have a high growth potential. The underlying dimension of these product options are the real options that will be described in the following paragraph.

2.4.3 Option types

The second level of real options is the different option types that involve a product option. Here, the categorization of Huchzermeier and Loch (2001) is a common used classification. As mentioned before, this classification is not the only used classification. Huchzermeier and Loch (2001) present option types as the option to defer, option to abandon, option to expand, and option to switch. Often, the second level consists of different option types that are related to one product option on the highest level. This can be seen as a chain of real options. In this way, a chain of options can exist in for example the following way. The option to expand for production is acquired if and only if the option to introduce a product is exercised. The underlying asset for the introduction option includes both the value of the operating cash flows associated with the product itself and the present value of the option to expand. Likewise, the option to expand a second time for commercial product production is acquired only if the company decides to exercise its first expansion option. Off course, several other chains of options can exist. Normally, companies use specific patterns of real options. Both levels are presented in figure 2.1.

Product options

Option types

	Product 1	Product 2	Product 3		Product X
Type 1	abandon	abandon	abandon		abandon
Type 2	expand	expand	expand		expand
Type 3	switch	switch	switch		switch
Type 4	defer	defer	defer		defer
Type X					

Figure 2.1: Product options versus option types (based on Huchzermeier and Loch, 2001)

2.4.4 Strategy as a portfolio of real options

Although the real options theory started off as a tool for valuating investments within uncertain environments, it more becomes into a strategic real options paradigm (De Schryver and Asselbergh, 2003; Bowman and Moskowitz, 2001; Adner and Levinthal, 2004a; Li and Johnson, 2002). Real options strategy is defined as a firm's strategy to manage risk and uncertainty by pursuing multiple product options with high growth potential and high uncertainty, while further investments into product options are only made if uncertainty has been resolved (McGrath, 1999; McGrath et al, 2004; Podoynitsyna, 2008).

McGrath and Nerkar (2004) present a relationship between real options and strategic investments. They argue that strategy is about making resource commitments before the relationship between these commitments and their potential performance outcomes are fully understood. They present options as an important mechanism through which firms reduce the strategic risk of making commitments.

When executives create strategy, they project themselves and their organization into the future, creating a path from where they are now to where they want to be in some years down the road. Generally, in a highly competitive market, no one expects to formulate a detailed long-term plan and follow it mindless (Luehrman, 1998). As soon as executives start with the path, they begin to learn about business conditions, competitors, regulations, and so forth. Therefore, they need to respond flexibly to what they learn.

An option-based approach to flexibility recognizes that flexibility seldom takes the form of a single option but instead typically is presented as a combination of real options (Trigeorgis, 1993). Smart companies have learned that the best way to respond effectively to future challenges is to deploy patterns of options (McGrath and Boisot, 1998). Rather than making a single bet on one attractive opportunity, they have found that it makes more sense to fund several small projects intended to capture market opportunity in different ways (McGrath and MacMillan, 2000). These small projects can be considered as a portfolio of real options. This bundle of real options consists of different product opportunities that can be seen as different product variances. As mentioned before, the product opportunities have underlying real options, namely the possibility to develop the product, introduce the product, expand capacity for manufacturing the product, and so forth. Because of the availability of fewer resources, new technology ventures often have only one product option with underlying options, instead of a large product option portfolio. Figure 2.1 presents the two dimensions considered in this paragraph.

A reason to use real options into strategy forming is mentioned by McGrath and MacMillan (2000). They argue that a real options approach allows a company to create focus and strategic alignment across their portfolio of initiatives. In addition to this strategic alignment, a long-term focus needs to be maintained. One way to do this is to think of options chains where each option buys the right to purchase future options (Faulkner, 1996). These options chains can be seen as fitting a firms' strategic challenges by linking current actions to uncertain futures (Adner and Levinthal, 2004a).

Science has confirmed the close tie between real options and strategic decision making (Bräutigam et al., 2009). Both instruments sharing the goal to maximize the return and hence the shareholder value (Amram and Kulatilaka, 1999b). Bräutigam et al. (2009) present the relationship between strategy and real options as a bi-directional relationship. Strategy influences real options and the valuation of real options influences strategy. Furthermore, real options can be used in discovering the potential of a strategy. Considering a portfolio of both product options and option types, the question rises whether these options are interacting with each other.

2.4.5 Option interactions on two levels

Some papers exist in which a framework is presented that is built on the notion that strategy is a chain of real options that interact with one other (Luehrman, 1998). Generally, real options logic makes a fundamental contribution to the structuring of risk. To reduce risk, companies purchase multiple real options and so create a portfolio of real options. This portfolio consists of product options and the underlying option types. Within this portfolio, it seems acceptable that options interact with each other and in this way, have influence on each other. Option interaction can take place in two dimensions: either options may be correlated within a compound option (an option composed of two or more options) or within a portfolio of projects. Few authors have addressed the issue of option interaction, but Trigeorgis (1993) has focused on the interaction phenomenon, and demonstrated that multiple real options in one project may not be valued separately. Here, real options are considered on the second level of analysis, real options within one product option. For example, an option to abandon eliminates the value of the underlying asset and thus renders all other option obsolete and worthless and options to alter the scale change the value of underlying asset and thus influence all options onwards (Trigeorgis, 1998). Options that are sequential to other options are expected to be highly correlated. Furthermore, he identified the option characteristics influencing the correlation with other options within a project or a firm. In his book he examines the size and type of interaction among the option to defer, abandon, expand, and switch. Here, the same categorization as Huchzermeier and Loch (2001) is used. He argues that real options may interact for various reasons and to varying degrees. Furthermore, he argues that the degree of interaction is related to the type of embedded options and the degree of overlap.

On the highest level of option analysis, the different product options, also interaction can be assumed. As mentioned in the illustration of the garden of tomatoes in the next paragraph, it seems logical that the condition of one tomato actually affects the size or ripeness of another nearby. Therefore, it can be suggested that product options next to each other in the portfolio, e.g. product 1 and 2, are more likely to be interacting than product option far away from each other, e.g. product option 1 and 9.

Also, Brosch (2001) presents some issues surrounding option interaction. He argues that if projects are independent of each other no interaction exists between the real options. In addition, he mentions some situations in which option interactions exist. When option interactions exist, it is necessary to valuate the whole portfolio of real options instead of all options on their own. Conclusively, it can be said that no consensus exists whether options are correlated with each other or not and what the underlying reasons are. Furthermore, it is not known whether all options are interacting with each other or whether some types of options are not correlated with each other. Empirical research is necessary to investigate possible interactions among real options and to study the interaction among different types of options. This can be an interesting research topic.

2.4.6 An illustrative example

Luehrman (1998) gives an example of managing a portfolio of strategic options. He compares it with growing a garden of tomatoes in an unpredictable climate. When you walk into the garden on a given day in August, you will see that some tomatoes are ripe and perfect. These tomatoes can be picked immediately, while other tomatoes are rotten and no gardener would ever bother to pick them. These cases at the extremes, now and never, are easy decisions for the gardener to make. In between these extremes, are tomatoes with varying prospects. Some tomatoes are edible and could be picked now but would benefit from more time on the vine. The experienced gardener picks them early only if competitors are likely to get them. Other tomatoes are not yet edible, and there is no point in picking them now. However, they are sufficiently far along, and there is enough time left in the season, that many would be ripen unharmed and eventually be

picked. Still other tomatoes look less promising and may not ripen before the season ends. Finally, there are some tomatoes that have little likelihood of growing and ripening before the season ends. There is no value in picking them.
Most experienced gardeners are able to classify the tomatoes in their gardens at any given time. Beyond that, good gardeners are able to understand how the garden changes over time. Early in the season, none of the tomatoes fall into the now or none categories. By the last day, all of the tomatoes fall into one or the other because time has run out. Here, the following interesting question rises. What can the gardener do during the season, while things are changing from week to week?
Here, a distinction can be made between a purely passive gardener and an active gardener. The first one visits the garden on the last day of the season, picks the ripe tomatoes and goes home. A weekend gardener visits his garden frequently and a very active gardener does much more. Based on what he sees he also cultivate the garden; watering, fertilizing, and weeding, trying to get more of those in-between tomatoes to grow and ripen before time runs out. Of course, the weather is always uncertain, but it is expected that the active gardener enjoy a higher yield in most years than a passive gardener.
In terms of options, active gardeners are doing more than merely making exercise decisions (pick or do not pick). They are monitoring the options and looking for ways to influence the underlying assets. This can be compared with executives making decision about product options. Furthermore, the executives have underlying options to influence the product options. We hope that this illustration is helpful in understanding the meaning of a portfolio of real options.

2.5 Summary of literature gaps

The previous parts have presented an overview of interesting literature concerning the construct of real options strategy. Several topics for future research are described and these will be summarized in this paragraph.
First, an interesting topic is to investigate what the boundaries of the theory are. As presented by Adner and Levinthal (2004a) it is important to understand a theory's boundaries to make it more powerful and more precise. This seems to be an interesting topic.
Second issue is the classification of the different options. Several classifications are described in literature (Brosch, 2001; Copeland and Keenan, 1998; Huchzermeier and Loch, 2001; Mauboussin, 1999) and some differences and some similarities exist but no consensus exists about the classification. Here, empirical research is necessary to examine whether for example the categorization of Huchzermeier and Loch (2001) is appropriate or what other categorization will be more appropriate.
Third, it needs to be investigated whether the results of the exploratory factor analysis can be validated. A conceptual model of the dimensions of real options strategy can be presented and this needs to be validated with empirical data. Then more knowledge is gathered about the conceptual presentation of the real options strategy construct.
Furthermore, it can be said that no consensus exists whether options are correlated with each other or not and what the underlying reasons are. There is no empirical evidence whether product options are correlated with each other and whether the underlying option types are correlated with each other. It is also not known whether all underlying option types are related to each other or if only some types are highly correlated to each other. Empirical research is necessary to investigate possible interactions among real options and to study the interaction among different

types of options. This can be an interesting issue for future research. This analysis of interaction is also important in the consideration of the following literature gap.

Less is known about the relationship between underlying dimensions and the real options construct. It is not clear whether the dimensions present real options strategy as a reflective or formative construct. Podoynitsyna et al. (2009) present the real options strategy as a reflective construct, but also indications exist that the real options construct can be conceived as a formative construct, where each dimension represents a different kind of real option that a firm can use. In this way, the real option construct would be considered as formative while firms do not have to use all different kinds of real options simultaneously. Furthermore, in determining whether we need to model it as a formative or reflective model it need to be tested whether all or just some options are interacting with each other. If all are interacting is seems more logical to model real options strategy in a reflective way. This needs to be tested. Future research should investigate these different conceptualizations of real options strategy.

Final interesting issue is the influence of the different options types on the performance of a new technology venture. It is not known what kind of option has the greatest influence on the performance and what types have less influence on a new technology venture's performance. Here, empirical research is necessary to fill this research gap.

These implications for further research are interesting to investigate. In this research study, we try to find an appropriate way to present the concept of real options strategy in new technology ventures. To deepen this issue, we investigate which classification of option types is most appropriate and whether these option types are correlated which each other or not. Furthermore, the gap whether to choose for a more reflective or formative way of modeling the concept of real options strategy is tried to be filled. Finally, the influence of the different real option types on the performance of a new technology venture is investigated.

3 Research Design

In this chapter, the research method will be described. This method will be used in order to answer the research questions. This research design is a typical example of a quantitative research method (Shah and Corley, 2006). First paragraph will present the main research question and the sub questions. Second paragraph will describe the type of research and gives an argumentation why a quantitative method will be the most useful approach in this study. The third paragraph will go into detail about the proposed research methodology. This paragraph will present the different research steps, the method of data collection, and the way data analysis will be done.

3.1 Research questions

In the conducted literature review, I have discussed the current state of academic literature on the topic of real options strategy. In addition, several research gaps are presented and in this section, the research question and several sub questions will be presented in order to define the scope of this research. The general research question in this study is the following:

What is an appropriate way to present the concept of real options strategy in new technology ventures?

To answer this question, I introduce several more detailed research questions. First, the classification of the different option types is an important issue. Previous paragraphs have described the different classifications presented in literature (Huchzermeier and Loch, 2001; Sadowski, 2007; Copeland and Keenan, 1998; Mauboussin, 1999; Brosch, 2001; Trigeorgis, 1996; Bruun and Bason, 2001; Amram and Kulatilaka, 1999b; Pleines, 2006). Nevertheless, it is not known which classification is appropriate involving new technology ventures. Therefore, the following sub question will be tried to be answered in this study.

Q1. *What classification of option types presented in literature is an appropriate way in defining the concept of real options strategy in new technology ventures?*

In addition, it is likely that the different option types are having influence on each other. In other words, we can suppose that these different option types are correlated to each other. As mentioned in previous paragraphs, Trigeorgis (1998) argues that the degree of interaction among real options is related to the type of embedded options and the degree of overlap. It is not known whether all options are interacting with each other or whether some types of options are not correlated to each other. Therefore, the following research question is proposed in order to investigate the issue of option correlation.

Q2. *To what extent are the different option types correlated to each other in new technology ventures?*

Third, a gap in literature exists about whether the concept of real options strategy in new technology ventures has to be modeled in a formative or reflective way. Podoynitsyna et al. (2009) present the real options strategy as a reflective construct, but also indications exist that the real options strategy construct can be conceived as a formative construct, where each dimension represents a different kind of real option that a firm can use.

Q3. *Does the concept of real options strategy in new technology ventures be presented in a formative or reflective way?*

In addition to the abovementioned research questions, an interesting question raises. The influence of the different option types on a new technology venture's performance has never been discussed. This has some practical implications for managers when more knowledge is gathered on this issue. Therefore, a fourth sub question has been defined.

Q4. *What is the influence of the different option types on a new technology venture's performance?*

To my knowledge, a focused discussion of these research questions has been lacking in the literature so far. This study aims at closing the gap, providing an appropriate way for conceptualizing and operationalizing the construct of real options strategy involving new technology ventures. Based on these research questions, the following research type seems appropriate.

3.2 Research type

As mentioned before, this study will be a quantitative research. Quantitative research is the systematic scientific investigation of quantitative properties and phenomena and their relationships. The main objective of quantitative research is to develop and employ mathematical models, theories, or hypotheses pertaining to natural phenomena. The process of measurement is central to quantitative research because it provides the fundamental connection between empirical observation and mathematical expression of quantitative relationships. Generally, quantitative research includes the generation of models, theories, and hypotheses or the development of instruments and methods for measurements or the collection of empirical data of finally the modeling, collection, and results of data (Muijs, 2004).

Some disadvantages of quantitative research can be presented. First, it is hard to explore a problem in depth. Quantitative research is good at providing information in breath from a large number of units. But when researchers try to investigate problems in depth, a quantitative research method is too shallow. To really create a depth view on a phenomenon, depth-interviews, in-depth case studies, and other qualitative techniques are necessary.

Secondly, quantitative research is well-suited for the testing of theory and hypotheses. Quantitative methods can not develop theories or hypotheses. Normally, these follow from literature studies or can be a result of explorative qualitative research.

Thirdly, when issues to be investigated are particularly complex, an in-depth qualitative study (a case study for example) is more likely to pick up on this than a quantitative study does. This problem is two-sided. On the one hand, there is a limit to how many variables can be looked at in any quantitative study. On the other hand, in a quantitative research it is the researcher who defines the variables to be studied. In qualitative research, it is more likely that unexpected variables emerge. Finally, while quantitative research methods are better at looking at cause and

effect, qualitative research methods are more suited to looking at the meaning of particular events of circumstances (Muijs, 2004).
Taking these disadvantages into account, a research methodology will be presented based on Coltman et al. (2008) in order to find answers on the proposed research questions. The way we propose to do this will be presented in the following paragraph.

3.3 Research methodology

As mentioned before, the proposed research will try to further explore the concept of real options strategy. With a central research question and several underlying sub questions the scope of this research is defined. The previous paragraph has described why the proposed framework of Coltman et al. (2008) seems to be an appropriate research method and the following sub paragraph will describe the research method in deeper detail. First, the steps are described that help the researcher to design and validate the models. Second, the data collection method will be proposed and finally, the intended way to analyze the gathered data will be presented.

3.3.1 Research steps

Coltman et al. (2008) present a framework that helps researchers to design and validate both formative and reflective measurement models. In their paper, they start with a theoretical justification to define the nature of the focal constructs, and then employ a series of empirical tests to support the causal direction between constructs and their measures. The framework of Coltman et al. (2008) builds on Jarvis et al. (2003) who provide some decisions rules for deciding whether the measurement model should be formative or reflective. In this part, the theoretical and empirical considerations will be described.

Step	Consideration
	Theoretical considerations
1	The nature of the construct
2	Direction of causality
3	Characteristics of indicators
	Empirical considerations
4	Item intercorrelation
5	Item relationships with construct antecedents and consequences
6	Measurement error and collinearity

Table 2: Framework of Coltman et al. (2008)

Theoretical considerations

As Coltman et al. describe, three broad theoretical considerations are important in deciding whether the measurement model is formative or reflective. Here, these considerations will be described.

1. The nature of the construct

Starting with the reflective model, the latent constructs exists independent of the measures. This way of modeling is typically used in measures of attitudes and personality. Practically, all scales in business related methodological texts on scale development use a reflective approach to measurement. In contrast to the reflective way of modeling, formative models include a latent construct that depends on a constructivist, operationalist of instrumentalist interpretation by the scholar (Borsboom et al., 2003). This way of modeling is less used in business literature.

2. Direction of causality

The second consideration taken into account to decide whether a model is reflective or formative is the direction of causality between the construct and the indicators. As presented in Coltman et al. (2008), reflective models assume that causality flows from the construct to the indicators, while in formative models it is the other way around. Therefore, in reflective models, a change in the construct causes a change in the indicators. In formative models, it is the other way around. This supports that both models presented in Coltman et al. are different in psychometrically and conceptually sense.

3. Characteristics of indicators

As Coltman et al. (2008) suggest, significant differences are present in the characteristics of the indicators that measure the latent constructs under reflective and formative scenarios. In the reflective model, the indicators all share a common theme and are interchangeable. This interchangeability enables researchers to measure the construct by sampling a few relevant indicators underlying the domain of the construct. Exclusion or inclusion of one or more indicators from the domain does not necessarily alter the content validity of the construct. Another situation occurs considering the formative way of modeling. In this case, the indicators define the constructs and the construct is sensitive to the number and types of the indicators the researcher selects. By adding or removing one indicator, a change can occur in the conceptual domain of the construct.

Empirical considerations

In addition to these theoretical considerations, three empirical considerations inform understanding of the measurement model. These considerations will be explained below.

4. Item intercorrelation

As argued by Coltman et al. (2008), in a reflective model the underlying construct drives the indicators, which have positive and, desirably, high intercorrelations. Contrary, in formative models indicators have no preconceived pattern of intercorrelation and they do not necessarily share the same theme. In formative models, indicators can theoretically possess no intercorrelation or high or low intercorrelation. To verify this, the researchers should check that indicator intercorrelations are as they expect. These checks are a necessary part in the analysis. Furthermore, the dimensionality of the construct needs to be consistent with the researcher's hypothesis. Another check is the issue that the correlations between items and construct have the expected directionality and strength. Here, bivariate correlations or factor or regression analysis seems to be helpful.

Since reflective indicators have positive intercorrelations, researchers are able to use statistics such as factor loading and communality, Cronbach's alpha, average variance extracted, and internal consistency to empirically assess the individual and composite reliabilities of their indicators (Trochim, 2007). Contrary to these tests, for formative models no simple, easy, and universally accepted criteria exist for assessing their reliability (Coltman et al., 2008).

5. Item relationships with construct antecedents and consequences
Considering a reflective modeling technique, the indicators have a similar relationship with the antecedents and consequences of the construct. These relationships can be positive/ negative and significant/insignificant. Interrelated indicators are not required elements for formative indicators as they do not have the same types of linkages with the antecedents and consequences of the construct. Using formative models, this lack of a common theme is a central issue, particularly as it has implications for the appropriate level of aggregation of formative indicators. For formative models, some possible approaches are described in Diamantopoulos and Winklhofer (2001).

6. Measurement error and collinearity
The sixth and final consideration is the difference in treatment of measurement error between formative and reflective modeling. In the case of reflective measurement, all error terms associate with the observed scores and therefore, represent measurement error in the latent variable. The formative measurement model does not assume such a correlational structure. In the case of reflective measurement models, researchers can identify and eliminate measurement error for each indicator using common factor analysis. This elimination occurs because the factor score contains only that part of the indicator that is shared with other indicators, and excludes the errors in the underlying items. In the case of formative models, the only way to overcome measurement error is to design it out of the study before data collection (Coltman et al., 2008). To design it out of the study, Diamantopoulos (2006) has suggested two possible ways. The first one is to capture all possible causes of the construct. The second one is to specify the focal construct in such a way as to capture the full set of indicators. Both approaches exclude the error term. This will lead to the issue that contrary to reflective models, in formative modeling it is not possible to empirically assess the impact of measurement errors. However, Bollen and Ting (2000) have suggested a way that provides some assistance in assessing measurement error. They argue that the tetrad test is helpful. This refers to the difference between the products of two pairs of error covariances. This tetrad test is a confirmatory procedure and cannot be used as a procedure on its own to distinguish between formative and reflective models. Coltman et al. (2008) argue that two reasons can exist when the tetrad test rejects the hypothesis that the errors are uncorrelated. The first one is that the construct is better measured formatively instead of reflectively. The second reason is that reflective measurement is more appropriate but the error structure is contaminated.

3.3.2 Sample and data collection
In this study, we can make use of a database that is used in a study of Podoynitsyna (2008). This paragraph will describe how this data is gathered and why this data is used. The sample frame was consisted of 11,029 venture-backed young technology firms in the VentureOne 2001 database and 982 new technology venture firms who were members of the 1995-2000 *Inc 500* (this is a listing of the fastest growing private companies in the United States, as selected by Inc magazine). As mentioned in Podoynitsyna (2008), 2,000 new technology ventures were randomly selected for the survey. The first mailing packet included a project fact sheet, a personal letter, the survey, a priority postage-paid envelope with an individually-typed return address label, and a list of research reports available to participants. Due to some undelivered mail addresses the adjusted samples consisted of 1,431 new technology ventures. With follow-up mailings and letters, the response rate was tried to be increased. After these efforts, a response

rate of 420 firms was achieved. In this research, we use only the abovementioned items of the database.

4 Explorative Analysis

This part of the analysis consists of three paragraphs. First paragraph will give a presentation of the item description based on literature. Second paragraph will focus on the explorative factor analysis trying to present empirical evidence for a typical classification based on literature. Third paragraph presents a deeper analysis of the data and an appropriate fit is proposed. Fourth paragraph will emphasize the main results of the explorative analysis.

4.1 Item Description

In this research, a part of the survey of Podoynitsyna et al. (2009) will be used (Appendix A). This survey is focused on entrepreneurial risk management strategies and real options strategy can be seen as one of these. In this survey, nine questions were focused on real options strategy with main issue the different option types. In this document, their relationships with the literature will be taken into account and the option types will be related to different classifications.
This fit is created by logical reasoning and some literature. In table 4.1, an overview is given of the different items asked in the questionnaire and the different categorizations.

The first item used in the survey is the following:
RO1: *If uncertainty surrounding a new envisioned product is too high, we defer developing it until more information has become available.*
This involves the defer option which refers to the possibility of waiting until more information has become available (Huchzermeier and Loch, 2001). In terms of the classification by Copeland and Keenan (1998) this is a defer/learn option. During the waiting time, companies can learn about the uncertainties and can decide later on whether to continue developing it or not. Pleines (2006) will present this item as an option to wait. As can be seen, most classifications agree on this type of option.

The second item used in the survey is the following:
RO2: *We invest in new products in stages – deciding at each stage, based on newest information, whether to proceed or whether to stop.*
In terms of Huchzermeier and Loch (2001), this involves the abandonment option which offers the possibility to make the investment in stages, deciding at each stage, based on the newest information, whether to proceed further or to stop. In terms of the classification by Copeland and Keenan (1998) this is a defer/learn option. During the time between different investment periods, companies can learn and gather new information and can decide whether to proceed or to stop. Trigeorgis should argue that this is a time-to-build option, while Pleines (2006) should argue for a stage/learn option. Most classifications agree on this item.
This option prevents losing revenues by not having to close down a part of the plant and ending up with the optimal decision (Mun, 2002). Furthermore, in manufacturing projects in which there is an active second hand market for the capital equipment, these options are extremely common to use. The abandonment option limits the project's downside exposure since the worst outcome is the project's salvage value (De Maesenaire, 2006).

Next item discussed is the item focused on the possibility to expand production:
RO3: *When starting work on a new product, we always make sure that we can expand the scale of the project if market conditions turn out to be more favorable than expected.*

Several authors (Brosch, 2001; Huchzermeier and Loch, 2001; Sadowski, 2007; Trigeorgis, 1998) would present this item as an option to expand or grow in production. This offers the possibility to wait with expanding the production until more is known about the market conditions (Huchzermeier and Loch, 2001). In terms of the classification by Copeland and Keenan (1998), this can also be seen as an invest/grow option.
This option may also be of strategic importance, especially if it enables a firm to capitalize future growth opportunities. A typical growth option is when a relative small investment will be done in a new emerging market with an initial small demand. The growth option gives the opportunity to expand the size of the investment in this similar market when demand is rising. For example, when a firm buys vacant undeveloped land, or when it builds a small plant in a new geographic location to position itself to take advantage of a developing large market, it essentially installs an option for future growth (Trigeorgis, 1998). Generally, the growth option is particularly valuable in high-tech or emerging industries (De Maesenaire, 2006).

Fourth item discussed in this report is the item focused on the option to switch product features to changing customer preferences.
RO4: *We intentionally develop our products in such a way that we can easily alter them if customer preferences change.*
In terms of Huchzermeier and Loch (2001), this involves the switching option and can also considered be as product flexibility. In terms of the classification by Copeland and Keenan (1998) this can be seen as a defer/learn option, while management has the opportunity to wait with the choice of the product design.
This enables a firm to keep the option open to switch among alternative outputs. This is more valuable in industries where product differentiation and diversity are important and/or product demand is volatile (Trigeorgis, 1998). This option gives the possibility to change product features when customer preferences change.

Next item is focused also on the development of the product.
RO5: *We intentionally develop our products in such a way that we can easily switch between different customer groups.*
This item involves the switching option and can be seen as output flexibility (Huchzermeier and Loch, 2001; Pleines, 2006; Trigeorgis, 1998). In terms of the classification by Copeland and Keenan (1998) this can be seen as invest/grow or disinvest/shrink option, the scope will be changed. Here, we choose for the option to shrink, because when management will switch to another customer group there will be disinvested in the project for the current customer group.
This option can be important when changing market circumstances exist. In response to these changing market circumstances, management is able to alter the output mix. As mentioned by Mun (2002), the switching option provides the right and ability, but not the obligation to switch among different sets of business operating conditions, including different technologies, markets, or products.

RO6: *We intentionally develop our products in such a way that we could easily introduce new related products if our competitors start threatening our market share.*
This can be seen as a combination of a switching option and an option to defer, since a company can keep the options open to switch to other market activities with new related products (Huchzermeier and Loch, 2001; Sadowski, 2007). In this view, we categorize this as an option to

switch. In terms of Copeland and Keenan (1998), this can be seen as invest/grow option. In addition, the option to disinvest in the current market is available in this item. This option gives a competitive advantage over other companies, while it gives the possibility to introduce new related products if the market share will be threatened. In terms of Pleines (2006) this item is related to the option to change scope.

Seventh item is also focused on the option to switch and gives the option to adapt to changes in industry standards.
RO7: *We intentionally develop technology for our products in such a way that it can easily accommodate changes in industry standards.*
Here, in terms of Huchzermeier and Loch (2001), Sadowski (2007), Trigeorgis (1996), and Pleines (2006) the switching option can be recognized, since the industry standards can be seen as input factors in for example the production process. In terms of the classification by Copeland and Keenan (1998), this is an invest/grow option. This can be compared with the option considered in the sixth item.
In fact, the firm should be willing to pay a certain positive premium for such a flexible technology over the cost of a rigid alternative that confers no or less choice. In this way, a firm that develops extra uses for its assets may have a significant advantage over its competitors (Trigeorgis, 1998). Generally, process flexibility can be achieved not only via technology, but also by maintaining relationships with a variety of suppliers and switching among them as for example relative prices change.

The eighth item is also focused on the switching option.
RO8: *We intentionally develop our products in such a way that they can easily be adapted to use a different technology, should the current one become out-dated.*
Many researchers (Huchzermeier and Loch, 2001; Sadowski, 2007; Trigeorgis, 1998; Pleines, 2006) should present this option type as a switching option. In terms of the classification by Copeland and Keenan (1998) and Mauboussin (1999) this is an invest/grow option, while it is a flexibility option to switch up. The technology standards can be seen as an input for the manufacturing process.
Here, a firm can change to another technology when there is a reason for. Reasons can be that a new technology is cheaper, has higher performance, or can be used to get more advanced products. This option allows a company to react on new technologies and future developments.

The ninth and final item used in the questionnaire is focused on the option to defer.
RO9: *When developing new products, we try to keep our technological design options open until we have enough information to make a choice.*
In addition to the first and second item, this item involves the option to defer and is focused on the possibility that a company can wait to invest until more information has become available (Huchzermeier and Loch, 2001). This also can be seen as a defer/learn option (Copeland and Keenan, 1998). This allows a company to wait with a certain decision about the technological design, until it has achieved more information about the best decision. A company can learn about the specific uncertainty in this period. All classifications should present this item in the same way as items one and two. Taking this paragraph into account, we can present the following table.

Item	Huchzermeier & Loch (2001)	Copeland & Keenan (1998), Mauboussin (1999)	Trigeorgis (1998), Brosch (2001)	Pleines (2006)
RO1	Defer	Defer/learn	Defer	Wait
RO2	Abandon	Defer/learn	Time-to-build	Stage/learn
RO3	Expand	Invest/grow	Expand	Grow
RO4	Switch	Defer/learn	Switch	Switch
RO5	Switch	Disinvest/shrink	Switch	Switch
RO6	Switch	Invest/grow	Switch	Change scope
RO7	Switch	Invest/grow	Switch	Switch
RO8	Switch	Invest/grow	Switch	Switch
RO9	Defer	Defer/learn	Defer	Wait

Table 4.1: Overview of item classifications

As can be seen in table 4.1, different possible option types can be related to the items. In addition to these items, two control variables are asked in the questionnaire. These control variables are based on Adner and Levinthal (2004a) who argue that firms that use real options strategy should show a higher percent of paused and stopped NPD projects than other firms. Therefore, the first variable is the percentage of projects paused by a firm and the second variable is the percentage of projects stopped completely by a firm. Beneath, the way these questions were asked is given.

PP: Among all the initiated new product development projects in your firm, what percentage of projects did you *pause for a certain time?*

PS: Among all the initiated new product development projects in your firm, what percentage of projects did you *stop completely?*

The survey in which these items are used has tried to tackle the dimensions of the real options strategy. Based on table 4.1, several possible bundles of items can be considered. For example, when we look at the classification by Huchzermeier and Loch (2001) we come up with the items RO1 and RO9 focusing on the defer option and items RO4, RO5, RO6, RO7, RO8 on the switching option. Looking at the items within the perspective of Copeland and Keenan, items RO1, RO2, RO4 and RO9 are focusing on the same option type. Also, items RO3, RO6, RO7, and RO8 are a bundle involving the invest/grow option and item RO5 is related to disinvest/shrink option. In this way, several different bundles of items can be presented, but still no empirical evidence exists whether these suggestions are supported. Therefore, in this report empirical evidence will be gathered.

4.2 Explorative Factor Analysis

This paragraph presents an exploratory factor analysis. The dataset used in this analysis is provided by dr. J.D. van der Bij and is adapted from a study of Podoynitsyna (2008). An exploratory factor analysis explores the data to find which factors are needed to best represent the data (Hair et al., 2006). First, the techniques used in the data examination process will be presented. Second, the assumptions of factor analysis are tested. Third, the results of the factor analysis will be presented.

Data examination

This paragraph describes the examination of data used in this analysis. The data underlying the analysis need to meet all of the requirements for a multivariate analysis. Missing data, outliers, and statistical characteristics of the data need to be checked. Therefore, a series of data examination techniques are used to check the data. After these checks, a complete dataset was available with 385 cases that can be used in our analysis. In the analysis, we focus on the items from RO1 to RO9. These items are measured on a 7-points Likert scale and a summary of statistics of the dataset is presented in table 4.2.

	N	Minimum	Maximum	Mean	Std. Deviation
RO1	385	1	7	5.37	1.452
RO2	385	1	7	5.11	1.507
RO3	385	1	7	5.01	1.570
RO4	385	1	7	4.47	1.551
RO5	385	1	7	4.34	1.684
RO6	385	1	7	4.83	1.559
RO7	385	1	7	4.29	1.823
RO8	385	1	7	3.98	2.012
RO9	385	1	7	5.10	1.456
Valid N (listwise)	385				

Table 4.2: Summary of descriptive statistics of the dataset

Testing Assumptions of Factor Analysis

Before moving on with the exploratory factor analysis, several assumptions are tested in order to establish the appropriateness of a factor analysis. First, all items should be normally distributed. A check of kurtosis and skewness shows that this is the case. Furthermore, a strong conceptual foundation needs to support the assumption that a structure does exist before the factor analysis is performed. Third assumption is that sufficient correlations exist among the variables to proceed. The Bartlett's test of sphericity is a statistical test for the presence of correlations among the variables. It provides statistical significance that the correlation matrix has significant correlations among at least some of the variables. A statistically significant Bartlett's test of sphericity (Sig. < 0.05) indicates that this is the case. Finally, the value of measure of sampling adequacy (MSA) must exceed 0.50 for both the overall test and each individual variable.

Variables with values less than 0.50 should be omitted from the factor analysis one at a time, with the smallest one being omitted each time. The overall measure of sampling adequacy is 0.781 which is middling (Hair et al., 2006).

Deriving Factors and Assessing Overall Fit

Now the variables are specified and the assumptions are tested, we are ready to apply factor analysis to identify the underlying structure of relationships. The extraction method used will be principal axis factoring. This common factor analysis is appropriate since we want to identify latent constructs and do not have a priori knowledge about the amount to specific error variance (Hair et al., 2006). The rotation method applied in the analysis is varimax, since this showed the most promising results. The analysis showed that three factors are derived. Looking at the eigenvalues it seems appropriate that three factors would be derived. We will now display the rotated solution for the factor analysis and elaborate on the important results. In table 4.3, the rotated solution is shown after deletion of the non-significant items. Significant items were those with a loading higher than 0.40 (Hair et al., 2006).

	Factor		
	1	2	3
RO2	0.863		
RO9	0.844		
RO3	0.783		
RO1	0.730		
RO5	0.650		
RO7		0.836	
RO6		0.700	
RO4			0.482

Table 4.3: The factor solution with Direct Oblim Rotation

Interpreting the factor matrix

Based on the factor loadings matrix a structure can be identified. In the abovementioned table, all variables have high loadings only on a single factor. RO1, RO2, RO3, RO5, and RO9 all load on the same factor. Furthermore, RO6 and RO7 load on the same factor, and RO4 loads on a separate factor when we consider loadings above 0.40. This gives an indication of the underlying structure. A confirmatory perspective needs to be used to check whether the proposed structure is valid. Interesting issue to mention is the fact that no classification of an author is in line with the results of the explorative factor analysis. Therefore, further analysis is necessary and this will be done in the following paragraph.

4.3 An appropriate fit?

Because no appropriate fit can be made between an author's classification and the explorative factor analysis, we need a deeper analysis trying to find a possible fit. To find a better fit, we adapt our data set. In this way, we only examine companies that have PP and PS variables that are above average. Therefore, in this analysis the data set is reduced to 123 cases and items RO1

to RO9. These data are examined in the same way as the previous paragraph. Missing data, outliers, and statistical characteristics of the data are checked. All items are normally distributed, a Bartlett test of sphericity shows that enough correlations exist. Finally, the value of Measure of Sampling Adequacy is 0.625 which is mediocre (Hair et al., 2006).
Now the variables are specified and the assumptions are tested, we are ready to apply factor analysis to identify the underlying structure of relationships. The extraction method used will be principal axis factoring. This common factor analysis is appropriate since we want to identify latent constructs and do not have a priori knowledge about the amount to specific error variance (Hair et al., 2006). The rotation method applied in the analysis is direct oblim, since this showed the most promising results.
The analysis showed that three factors are derived. Looking at the eigenvalues it seems appropriate that three factors would be derived. We will now display the rotated solution for the factor analysis and elaborate on the important results. In table 4.4, the rotated solution is shown after deletion of the non-significant items. Significant items were those with a loading higher than 0.50 (Hair et al., 2006), because this indicates practical significance.

	Factor		
	1	2	3
RO2	0.822		
RO1	0.792		
RO9	0.663		
RO3	0.633		
RO7		0.846	
RO6		0.799	
RO8		0.740	
RO4			
RO5			0.735

Table 4.4: Factor Loading Matrix with Direct Oblim Rotation

Comparing this rotated factor matrix with one of the previous mentioned classifications, it seems that the classification by Copeland and Keenan (1998) is almost the same as proposed in this factor analysis. RO6, RO7, and RO8 are bundled together in both the factor analysis and the literature analysis. Secondly, RO1, RO2, and RO9 are bundled together and RO5 is a factor on its own. RO4 loads on no factor and therefore will be deleted from the analysis. Problem is that RO3 is loaded on the same factor as RO1, RO2, and RO9, but we cannot assume a reason why this is the case. Therefore, we propose to delete RO3 from the analysis.
Now, the same analysis will be executed without RO3. This will result in the following table.

	Factor		
	1	2	3
RO7	0.839		
RO6	0.836		
RO8	0.760		
RO2		0.871	
RO1		0.854	
RO9		0.623	
RO5			0.896

Table 4.5: Results of the explorative factor analysis with direct oblim rotation

In this table, the same classification is presented as can be proposed by Copeland and Keenan (1998). Next paragraph will summarize the results of this chapter.

4.4 Results of the Explorative Factor Analysis

The results presented in this paragraph refer to the explorative factor analysis executed in previous paragraphs. In this analysis, the goal is to try to find an appropriate fit between the items used in the survey of Podoynitsyna et al. (2009) and current literature. In other words, the option types will be related to different option classifications presented in literature.

The results of the item description suggest that it is hard to find one universal categorization concerning the different option types. In table 4.1, the different possibilities are presented and for these classifications, we need to gather some empirical evidence.

In the second paragraph of this chapter, we used the dataset adapted from a study of Podoynitsyna (2008) to explore the data to find which factors are needed to best represent the data (Hair et al., 2006). Data examination shows that data meet all requirements for the multivariate analysis and the final data set consists of 385 cases.

After, analysing the dataset an appropriate fit can be suggested. In this analysis, only new technology ventures that have a PP and PS value above average are taken into account. Examining these data shows that three factors are derived. Looking at the eigenvalues it seems appropriate that three factors would be derived. The results of the rotated solution after deletion of non-significant items will be displayed in table 4.5. Significant items were those with a loading higher than 0.50 (Hair et al., 2006), because this indicates practical significance.

Table 4.5 presents the bundles of items related to the specific factors. Item 1,2, and 9 will define one factor. Furthermore, item 6, 7, and 8 will measure one factor, and finally item 5 will define one factor. In this table, the same classification is presented as can be proposed based on literature (Copeland and Keenan, 1998; Mauboussin, 1999). In the following chapter, we have tried to confirm these results.

5 Confirmatory Analysis and Results

In addition to the explorative factor analysis presented in the previous chapter, this chapter will describe the confirmatory factor analysis. In general, factor analysis is an approach for expressing in the language of mathematics hypothetical constructs by using a variety of observable indicators that can be directly measured (Raykov and Marcoulides, 2000). This analysis is confirmatory when a preexisting model of the relationship among indicators directs the search. In this case, confirmatory factor analysis is not concerned with discovering a factor structure, but with confirming the existence of a specific factor structure (Schumacker and Lomax, 2004). Hence, in a confirmatory factor analysis the theory comes first, the model is then derived from it, and finally the model is tested for consistency with the observed data using a SEM-type approach. As a starting point for the confirmatory factor analysis, it is required that the complete details of the proposed model are specified before fitting to the data. In this sense, Jöreskog and Sörbom (1993a) make a distinction between three situations concerning model fitting and testing: (a) the strictly confirmatory situation in which a single formulated model is either accepted or rejected, (b) the alternative-models or competing-models situation in which several models are formulated and one of them is selected, (c) the model-generating situation in which an initial model is specified and, if it does not fit the data, is modified and repeatedly tested until some fit is obtained. In this report, the second option seems to be the most appropriate approach.

5.1 Model 1: confirmatory three factor analysis

The first model we try to confirm is the model proposed in the explorative factor analysis. In this model, three latent variables are mentioned. The model proposes that three variables (RO1, RO2, and RO9) are indicators of the option to defer/learn, one variable (RO5) is indicator of the option to disinvest/shrink, and three variables (RO6, RO7, and RO8) are indicators of the option to invest/grow. Here, the primary interest is in estimating the relationships among these indicators and their latent variables. For the purpose of this study, data were collected from a sample of N = 123 new technology ventures. The following observed variables were used in the study:

1. If uncertainty surrounding a new envisioned product is too high, we defer developing it until more information has become available (RO1).
2. We invest in new products in stages – deciding at each stage, based on newest information, whether to proceed or whether to stop (RO2).
3. We intentionally develop our products in such a way that we can easily switch between different customer groups (RO5).
4. We intentionally develop our products in such a way that we could easily introduce new related products if our competitors start threatening our market share (RO6).
5. We intentionally develop technology for our products in such a way that it can easily accommodate changes in industry standards (RO7).
6. We intentionally develop our products in such a way that they can easily be adapted to use a different technology, should the current one become out-dated (RO8).
7. When developing new products, we try to keep our technological design options open until we have enough information to make a choice (RO9).

This conceptual model is presented in the following figure.

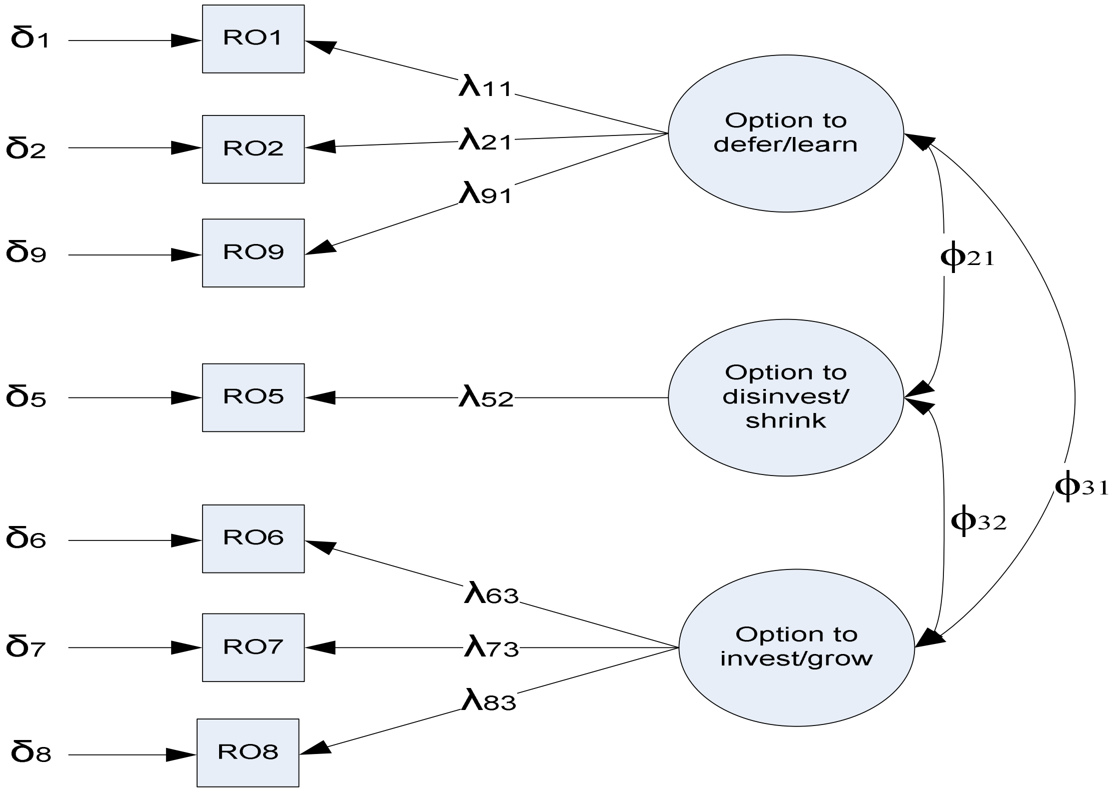

Figure 5.1: Conceptual three factor model based on EFA

This conceptual model is the basis for our confirmatory factor analysis. The confirmatory factor model depicts how the latent variables have been measured. The relationships between the latent variables and their corresponding indicators (i.e. manifest variables) are represented by arrows which originate at the latent variable and end at the indicators. Note that each indicator is also associated with an error term, the latter representing errors in measurement (since it is virtually impossible to perfectly measure even an observed variable).

Consistent with our conceptualization, there are seven directional relationships and the curved two-way arrows connecting the three factors represent non-directional relationship (i.e. do not distinguish between a dependent and an independent variable); they simply indicate that these variables are thought to be intercorrelated (Diamantopoulos and Siguaw, 2000). Note also that certain model assumptions are reflected in the absence of paths. Thus, the lack of an arrow between measurement errors reflects the assumption of uncorrelated measurement errors.

In this paper, we make use of the LISREL 8.80 student version for the analyses. SIMPLIS language will be used. In table 5.1, the SIMPLIS input file for the confirmatory factor analysis will be presented.

```
CFA based on EFA
Raw Data from file 'C:\Users\s030364\Documents\Documents\Studie\Master Thesis\Database\database version
1.6.psf'
Sample Size = 123
Latent Variables  Factor1 Factor2 Factor3
Relationships
RO1 = Factor1
RO6 = Factor3
RO5 = Factor2
RO9 = Factor1
RO7 = Factor3
RO8 = Factor3
RO2 = Factor1
Set the Variance of Factor1 to 1.00
Set the Variance of Factor3 to 1.00
Set the Error Variance of RO5 to 0.00
lisrel output: mi  sc
Path Diagram mi=5 tv=5
Wide Print
End of Problem
```

Table 5.1: SIMPLIS input model 1

This will lead to the following path model with standardized results. This path diagram is based on the LISREL 8.80 diagram which can be found in Appendix B.

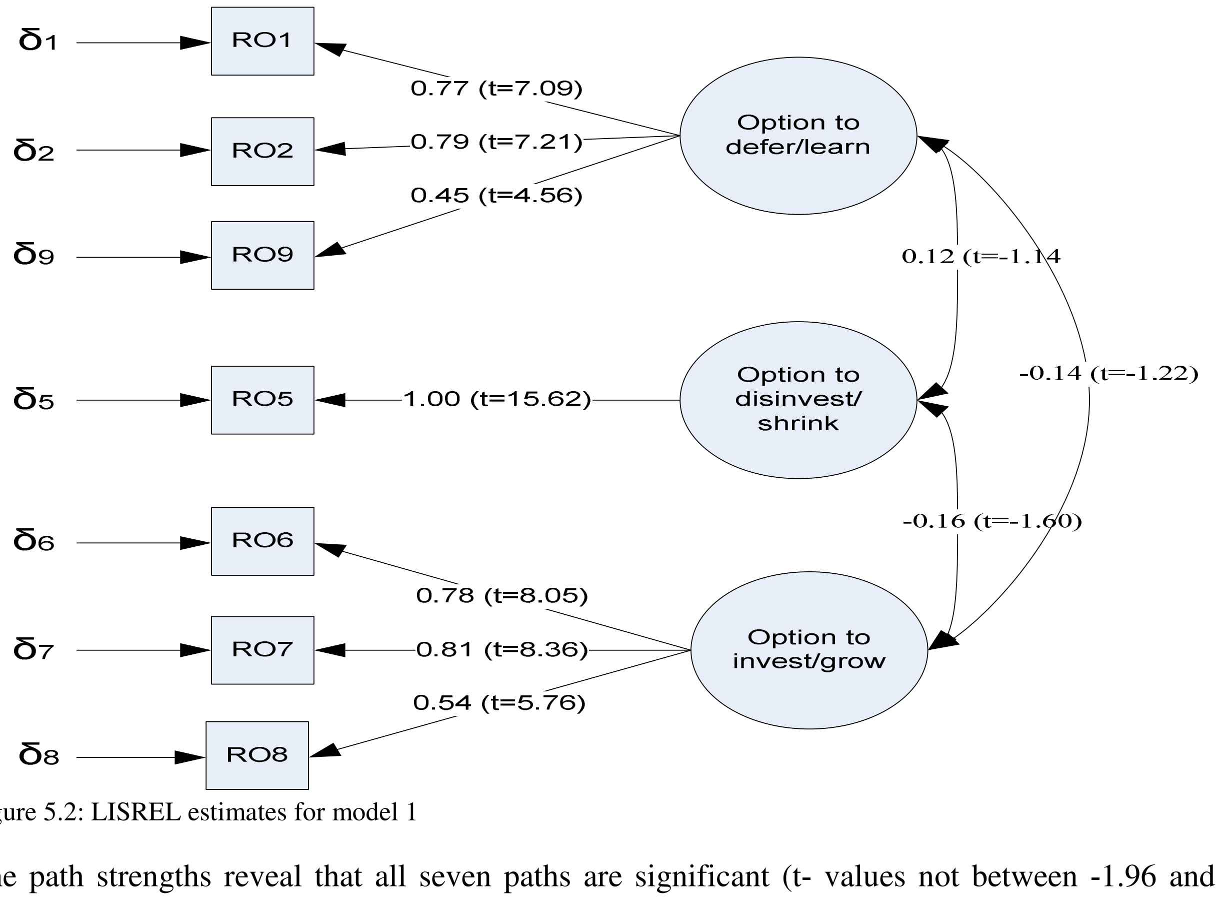

Figure 5.2: LISREL estimates for model 1

The path strengths reveal that all seven paths are significant (t- values not between -1.96 and 1.96). For directional linkages, a standardized parameter estimate shows the resulting change in a dependent variable from a standard deviation change in an independent variable. For non-directional linkages (i.e. covariances), standardized parameter estimates reflect simply the correlations between the variables involved (Diamantopoulos and Siguaw, 2000).

Overall fit assessment

As mentioned in the book of Diamantopoulos and Siguaw (2000), the purpose of assessing a model's overall fit is to determine the degree to which the model *as a whole* is consistent with the empirical data at hand. LISREL provides a wide range of goodness-of-fit indices that can be used as summary measures of a model's overall fit. This paragraph will present and describe the fit indices used in this report.

The first fit measure used is the chi-square statistic (in the output denoted as *Minimum Fit Function Chi-Square*). This chi-square statistic is the traditional measure for evaluating overall model fit in covariance structure models and provides a test for perfect fit in which the null hypothesis is that the model fits the population data perfectly. Therefore, a statistically significant chi-square causes rejection of the null hypothesis, implying imperfect model fit and possible rejection of the model.

The next measure to consider is the *root mean square error of approximation* (RMSEA). This measure is generally regarded as one of the most informative fit indices and shows how well the model would fit the population of the covariance matrix if it was available, with unknown but optimally chosen parameter values. Values less than 0.05 are indicative of good fit, between 0.05 and 0.08 of reasonable fit, between 0.08 and 0.10 of mediocre fit and >0.10 of poor fit.

The *goodness-of-fit-index* (GFI) is an indicator of the relevant amount of variances and covariances accounted for by the model and thus shows how closely the model comes from perfectly reproducing the observed covariance matrix. The *adjusted goodness-of-fit index* (AGFI) is simply the GFI adjusted for the degrees of freedom in the model, while the *parsimony goodness-of-fit index* (PGFI) makes a different type of adjustment to take into account model complexity. GFI and AGFI should range between 0 and 1 and values above 0.90 are usually taken as acceptable fits. Acceptable values of the PGFI are usually much lower values, sometimes even in the 0.50s. Generally, the GFI is recommended as the most reliable measure of absolute fit in most circumstances (Diamantopoulos and Siguaw, 2000).

The next fit measure, the *non-normed fit indices* (NNFI), shows how much better the model fits compared to a baseline model, usually the independence model. Other indices in the group of the NNFI have a range between 0 and 1 with values close to 1 representing good fit, but the NNFI can take values greater than 1.

The last fit index that will be presented in this paper is the *comparative fit index* (CFI). This fit index measures the improvement in non-centrality in going from one model to an alternative model. Here, measurement above 0.90 indicates an adequate fit and measurement above 0.95 indicates a good fit of the model.

Model	Chi-square	P-value	DoF	RMSEA	GFI	AGFI	PGFI	NNFI	CFI
1 (Three Factor Analysis)	16.86	0.15	12	0.058	0.96	0.91	0.41	0.95	0.97

Table 5.2: Fit Indices of model1

The fit indices of model 1 indicate a significant chi-square value of 16.86. Furthermore, the RMSEA measurement of 0.058 indicates a reasonable fit of the model. GFI and AGFI values which are higher than 0.90 indicate acceptable fits. As mentioned above, it is not strange that the PGFI value is much lower, namely 0.41. Finally, NNFI and CFI values are high (above 0.90) and therefore indicate a good fit. We can conclude that the LISREL output indicates that the proposed model can be accepted.

Modification Indices

A modification index shows the minimum decrease in the model's chi-squared value if a previously fixed parameter is set free and the model is re-estimated (Diamantopoulos and Siguaw, 2000). Focusing on the modifications aiming to improve a model's fit, relevant diagnostic information can be obtained by examining the modification index which form a part of the program output (Diamantopoulos and Siguaw, 2000). The highest modification index in the output file for model 1 is to set the covariance between the indicators RO8 and RO9 free. Because no theoretical base exists to set the covariance between these indicators free, we have no reason to implement this in the conceptual model.

Furthermore, the second largest modification index is not high enough to reconsider modification, therefore we can conclude that the abovementioned conceptual model can be accepted and can be proposed as the basis of further modeling.

Model 1 with additional variables

In order to create a model with more indicators, we try to get variable RO4 back in the model. Based on Copeland and Keenan (1998) we can relate RO4 in the same way to the option to disinvest/shrink as RO5. This conceptual model is presented in Appendix C. Furthermore, the standardized solution of the path diagram will be given. Now we can come up with the following table of fit indices.

Model	Chi-square	P-value	DoF	RMSEA	GFI	AGFI	PGFI	NNFI	CFI
1 (Three Factor Analysis)	16.86	0.15	12	0.058	0.96	0.91	0.41	0.95	0.97
1a (as 1 with RO4)	26.15	0.072	17	0.069	0.95	0.89	0.45	0.92	0.95

Table 5.3: Fit Indices of the conceptual models

The fit indices of model 1a indicate a significant chi-square value of 26.15. Furthermore, the RMSEA measurement of 0.069 indicates a reasonable fit of the model. GFI and AGFI values which are higher than 0.90 indicate acceptable fits. As mentioned above, it is not strange that the PGFI value is much lower, namely 0.45. Finally, NNFI and CFI values are high (above 0.90) and therefore indicate a good fit. The problem in model 1a is that the paths from respectively RO4 and RO5 to the option to disinvest/shrink seem to be not significant. Therefore, we will not keep RO4 in our conceptual model.

Looking at the modification indices proposed by the LISREL output, we can see that the highest modification index is focused on the covariance between RO4 and RO7. Because no theoretical base exists to set this covariance free we have no reason to modify our model.

Finally, we tried to get RO3 back in our conceptual model by relating this indicator to the option to invest/grow. Running this model in LISREL results in a model that does not fit very well. Furthermore, the path between RO3 and the option to invest/grow has no significant value.

Therefore, we suggest rejecting this model and keeping model 1 as the best one. In this model, all indicator loadings are significant (at $p < 0.05$ or better), as indicated by t-values well in excess of 1.96 in absolute terms. This provides validity in evidence in favor of the indicators used to represent the constructs of interest (Diamantopoulos and Siguaw, 2000).

5.1.1 Results of the three factor model

Based on seven items a three factor model was proposed. It is suggested that these three factors were based on the classification by Copeland and Keenan (1998). The confirmatory factor model depicts how the latent variables have been measured. Results indicate that all seven paths are significant, because the t-values are not between -1.96 and 1.96 (figure 5.2). Furthermore, the model's overall fit is assessed. This is done by LISREL in order to determine to which the model as a whole is consistent with the empirical data.
The fit indices of model 1 (table 5.2) indicate a significant chi-square value of 16.86. Furthermore, the RMSEA measurement of 0.058 indicates a reasonable fit of the model. GFI and AGFI values which are higher than 0.90 indicate acceptable fits. As mentioned above, it is not strange that the PGFI value is much lower, namely 0.41. Finally, NNFI and CFI values are high (above 0.90) and therefore indicate a good fit. Concerning these fit indices, we can suggest that the three factor model can be accepted. The purpose of this study is to model the construct real options strategy as a second-order model and therefore this model will be used as a base for the formative and reflective model.

5.2 Factor Correlation

This paragraph presents the factor correlation matrix of the abovementioned analysis (table 5.4). This is a correlation matrix between oblique factors patterns found through oblique rotation. It can be seen that some correlation among the factors exists and the data patterns themselves have a relationship, to the degree measured by the factor correlations.

Factor	Option to defer/learn	Option to disinvest/shrink	Option to invest/grow
Option to defer/learn	1.000	0.135	-0.057
Option to disinvest/shrink	0.135	1.000	0.000
Option to invest/grow	-0.057	0.000	1.000

Table 5.4: Factor correlation matrix

Table 5.4 presents that the option to defer/learn and the option to disinvest/shrink have some positive correlation with each other. Contrary, the option to defer/learn and the option to invest/grow have some negative correlation to each other. These correlation values are very low. Furthermore, it can be seen that the option to disinvest/shrink and the option to invest/grow have no correlation with each other; these are in fact orthogonal to each other.
In addition to the factor correlation analysis, literature on the aspect of the trade-off between different option types is taken into account (Mikaelian, 2009; Brennan and Schwartz, 1985; Folta and O'Brien, 2004). Mikaelian (2009) presents different examples of bundles of option types,

which he calls mechanisms, in which different option types are existing next to each other. Nevertheless, no systematic study of these mechanisms is available.
It seems logical that some option types are excluding each other. Brennan and Schwartz (1985) present the example of the exclusion of the option to open and the option to close a copper mine. It is not possible to execute both options together. Another example is stated as followed. The option to expand for production is acquired if and only if the option to introduce a product is exercised. In addition, the option to expand a second time for commercial production is acquired only if the company decides to exercise its first expansion option. Contrary, some options to invest/grow can be excluding each other. A firm has limited capital and therefore sometimes has to choose between different investment options. Simply, it is not possible to execute all options to invest. Folta and O'Brien (2002) examine the tension between the option to defer and the option to grow. They mention the exclusion between the option to defer/learn and the option to invest/grow. A firm continuously decides whether it should invest or wait until the next period and then decide whether to enter. Their results are almost in line with the results presented in this report, but it is hard to declare why there is still some correlation between these two factor.
We can conclude that some option types are somewhat correlated to each other, only the option to disinvest/shrink and the option to invest/grow are not correlated to each other. This issue needs to be taken into account in the consideration whether to model the construct real options strategy in a formative or reflective way. As with all effect size indices, there is no good answer to the question, "what value indicates a strong relationship between two variables?". What is large or small depends on the discipline within which the research question is being asked. However, correlation coefficients of 0.10, 0.30, and 0.50 irrespective of sign, are, by convention, interpreted as small, medium, and large coefficients, respectively (Green and Salkind, 2005).
As argued by Coltman et al. (2008), in a reflective model the underlying construct drives the indicators, which have positive and, desirably, high intercorrelations. Contrary, in formative models indicators have no preconceived pattern of intercorrelation and they do not necessarily share the same theme. In formative models, indicators can theoretically possess no intercorrelation or high or low intercorrelation. Because less correlation among the different option types exists we can argue for a formative way of modeling the construct real options strategy but to give a decisive answer about whether to model real options strategy in a formative or reflective way, more empirical research is necessary and so on several models will be proposed and checked.

5.3 Model 2: Real Options Strategy as a formative second-order construct

In the second proposed model, the construct real options strategy will be added. The previous paragraph has investigated whether factor correlation exists among the three factors in the conceptual model. This investigation results in the suggestion that some factor correlation exists among the factors in the proposed model, but no hard judgment can be made only based on this. Therefore, both models, formative and reflective, will be proposed and we try to indicate which model can be seen as the most appropriate.
Indications exist that the construct of real options strategy can be conceived as a formative construct, where each pair of items represents a different kind of real option that a firm can use. Formative scales are used when a construct is viewed as an explanatory combination of its indicators (Curtis and Jackson, 1962; Fornell and Bookstein, 1982). In this way, the construct of real options strategy would be considered as formative because firms do not have to use all

different kind of real options simultaneously and the construct is defined as a total weighted score across all the items.

It is a less common, but plausible approach to combine a number of indicators to form a construct without any assumptions as to the patterns of intercorrelation between these items. In this way, a formative or causal index results where causality flows from the indicator to the construct. In addition, variation in the construct of real options strategy is assumed not to cause variation in the item measures and variation in item measures causes variation in the construct of real options strategy.

The final theoretical consideration suggests that the items need not share a common theme and are not interchangeable. We can say that the different options types are different in this perspective; different option types are not interchangeable.

The conceptual model can be presented with real options strategy as a second-order formative construct and with three first-order dimensions of this construct. These dimensions are respectively the option to defer/learn, the option to disinvest/shrink, and the option to invest/grow. This conceptualization of real options strategy as a formative second-order construct with three dimensions of the option types provides the basis for this part of the analysis. Figure 5.3 will present the model that will be tested in this paragraph.

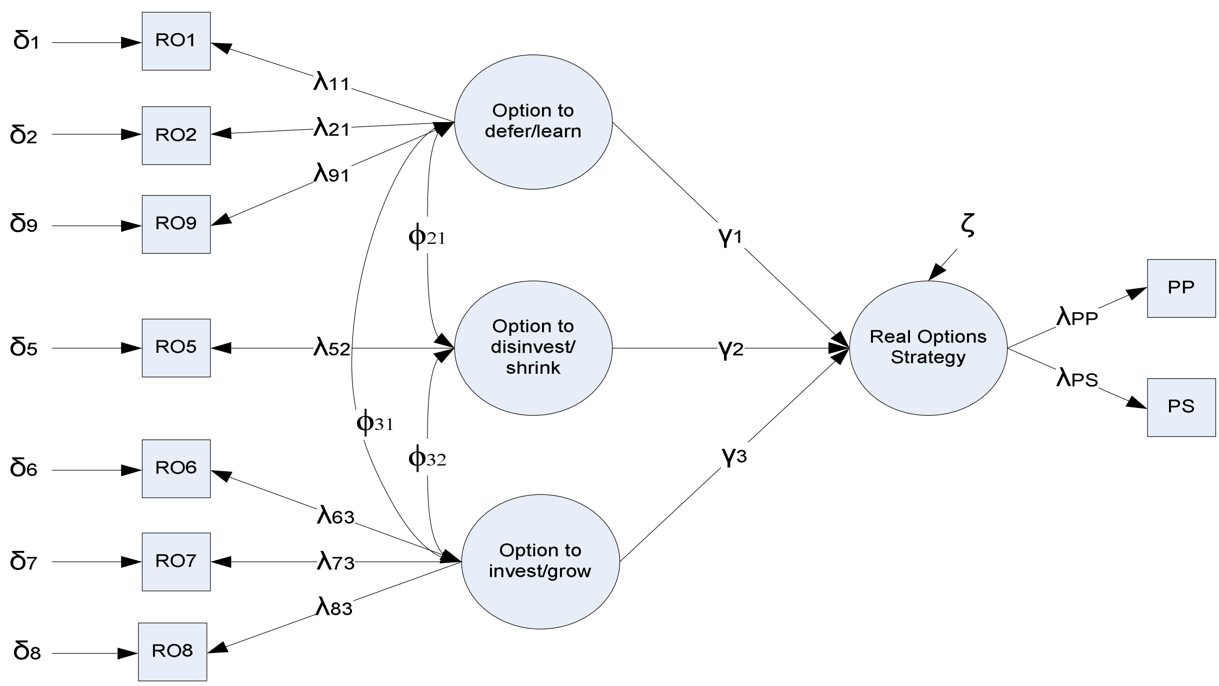

Figure 5.3: Real Options Strategy as a second-order formative construct

As mentioned by Jarvis et al. (2003), this is typically a type II model which is a reflective first-order, formative second-order model. This model has first-order factors as formative indicators and the first-order factors themselves have reflective indicators. The construct real options strategy is modeled as a second-order formative construct. Diamantopoulos and Winklhofer (2001) point out several characteristics of this model which make it sharply distinct from the reflective model. First, the indicators characterize a set of distinct causes which are not interchangeable as each indicator captures a specific aspect of the real options strategy construct's domain (see also Jarvis et al., 2003). Furthermore, adding or removing any of these components would change the conceptual interpretation of the construct (Coltman et al., 2008). This is the reason why the non-significant relationship between the option to invest/grow is not removed from the model, to fully describe the concept of real options strategy. Second, there are no expectations about patterns of magnitude of intercorrelations between the indicators; formative indicators might correlate positively or negatively or lack any correlation. Third, formative indicators have no individual measurement error terms, that is, they are assumed to be error-free in a conventional sense. The error term (ζ) is specified at the construct level, where it captures the amount of variance in the second-order construct which the first-order dimensions do not account for (MacCallum and Browne, 1993) and at the level of the manifest indicators, where it represents measurement error. In other words, the error term represents the surplus meaning of the construct (Jarvis et al., 2003; Temme, 2006) which is not captured by the set of formative indicators included in the model specification (Diamantopoulos, 2006; Diamantopoulos et al., 2007). Fourth, a formative measurement, in isolation, cannot be estimated and, therefore a reflective part is added. The option to add a reflective part is presented by Albers and Götz (2006). They describe that second-order constructs can be measured by introducing manifest indicators in order for operationalizing the construct. In this study, the items PP and PS will be used as tests for the construct real options strategy (Jöreskog and Sörbom, 1993a; Coltman et al., 2008). This type of modeling is only recently introduced and less literature provides empirical examples of its use.

This proposed model is based on model 1 with the addition of the real options strategy construct. Furthermore, indicators PP and PS are added in order to create the measurement model of real options strategy. In this paper, we make use of the LISREL 8.80 student version for the analyses. SIMPLIS language will be used. In Appendix D, the SIMPLIS input file for the analysis of model 2 will be presented. This will create the following path diagram.

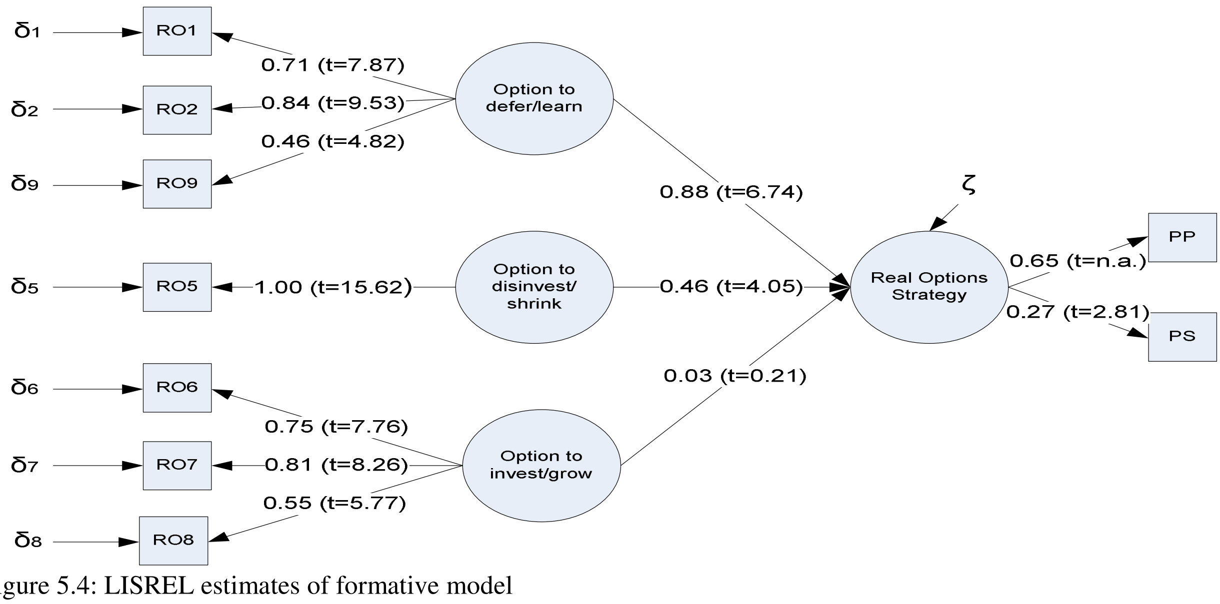

Figure 5.4: LISREL estimates of formative model

Modification index

The highest modification index that can be found in the LISREL output is in the THETA-DELTA matrix and is linked to the items RO1 and RO2. Here, a modification index of 5.79 suggests an improvement in model fit. Because we have no theoretical base to justify this modification, it does not seems reasonable to let the measurement errors associated with RO1 and RO2 correlate to each other. Therefore, we keep the model as it was originally. We can come up with the following fit indices.

Model	Chi-square	P-value	DoF	RMSEA	GFI	AGFI	PGFI	NNFI	CFI
2 (Formative model)	34.35	0.045	22	0.065	0.94	0.88	0.46	0.93	0.96

Table 5.5: Selection of the fit indices of the proposed models

Now, we have analyzed the formative way of modeling the real options strategy construct. Summarized results can be found in the final paragraph of this chapter. The following paragraph will try to investigate real options strategy as a reflective second-order construct.

5.4 Model 3: Real Options Strategy as a reflective second-order construct

According to this model, causality direction is expected to be from the construct real options strategy to the different dimensions. Therefore, the real options strategy construct should be specified as reflective in the second-order, where the different options types in the first-order are defining characteristics of the real options strategy construct.

In the reflective model, indicators are expected to share similar content and thus theme. The construct validity should be maintained even if a single indicator is dropped and therefore equally reliable indicators should be interchangeable (Jarvis et al., 2003). Dropping either component from the model changes the domain of the real options strategy construct. Under the formative model, each sub dimension is actually only a component of the whole, and the whole becomes incomplete if any components are missing (Lin et al., 2005).

The reflective way of modeling real options strategy assumes correlations between indicators. As analyzed in paragraph 5.2, some correlation exists among the factors and therefore we can propose the model drawn in figure 5.5.

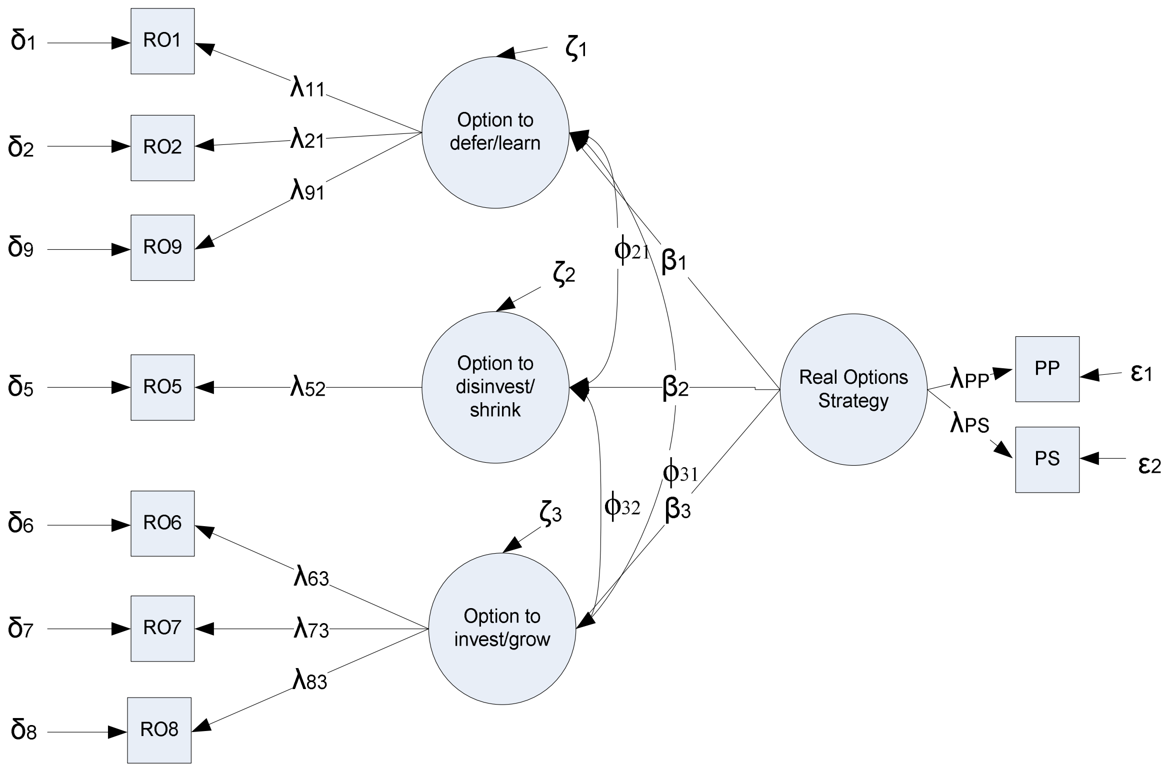

Figure 5.5: Conceptual reflective model (model 3)

As mentioned by Jarvis et al. (2003), this is typically a type I model which is a reflective first-order, reflective second-order model. This model posits a series of first-order latent factors with reflective indicators and also these first-order factors themselves are reflective indicators of the underlying second-order construct. The construct real options strategy is modeled as a second-order reflective construct. Jarvis et al. (2003) point out several characteristics of this model which make it sharply distinct from the formative model.

First, measures are expected to be correlated and dropping an indicator from the measurement model does not alter the meaning of the construct. Furthermore, measurement error is taken into account at the item level. This type of modeling can be found in many studies and is common used in literature.

This proposed model is based on model 1 with the addition of the real options strategy construct. Furthermore, indicators PP and PS are added in order to create the measurement model of real options strategy. In Appendix E, the SIMPLIS input file for the analysis of model 3 will be presented. This will lead to the following estimated path diagram.

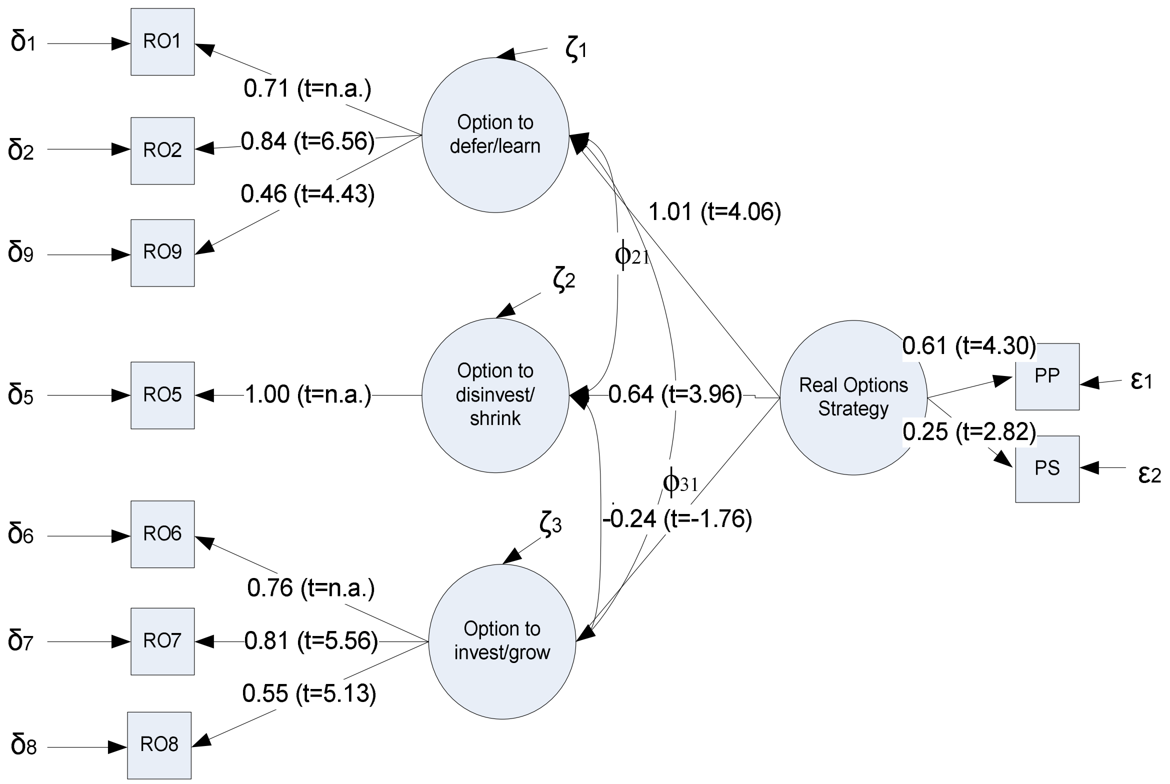

Figure 5.6: LISREL estimates of reflective model (model 3)

Modification index

The highest modification index that can be found in the LISREL output is in the THETA-DELTA matrix and is linked to the items RO1 and RO2. Here, a modification index of 5.71 suggests an improvement in model fit. However, we have no theoretical base to justify this modification, it does not seems reasonable to let the measurement errors associated with RO1 and RO2 correlate to each other. Therefore, we keep the model as it was originally. Although the comparison between first- and second-order measurement model is generally nested, the empirical comparison using a Chi-square statistic is not as useful as it is when comparing competing measurement models of the same order. The first-order model will always fits better in absolute terms because it uses more paths to capture the same amount of covariance. This complicates empirical comparisons (Hair et al., 2006). Therefore, in this paragraph, we only compare the two second-order models with each other and the following table will present the corresponding fit indices of the models described.

Model	Chi-square	P-value	DoF	RMSEA	GFI	AGFI	PGFI	NNFI	CFI
2 (Formative model)	34.35	0.045	22	0.065	0.94	0.88	0.46	0.93	0.96
3 (Reflective model)	34.73	0.055	23	0.061	0.94	0.89	0.48	0.93	0.96

Table 5.6: Selection of the fit indices of the proposed models

A Tetrad Test for Causal Indicators

Bollen and Ting (2000) propose a confirmatory tetrad analysis test to distinguish causal from effect indicators in structural equation models. A tetrad refers to the difference between the products of two pairs of error covariances (Spearman and Holzinger, 1924). The tetrad test involves examining the nested vanishing tetrads that a comparison of two different measurement models implies (Coltman et al., 2008). The tetrad test is a confirmatory procedure and not for use as a stand-alone criterion for distinguishing formative from reflective models. Specifically, if the test rejects the hypothesis that the errors are uncorrelated, it can be for one of two alternative reasons. One is that the construct is better measured formatively, not reflectively. Second is that reflective measurement is more appropriate but the error structure is contaminated.

In some rare cases it is possible to devise experiments that help to test whether variables are causal or effect indicators (Bollen, 1989), however this will be very difficult in most practical situations. Estimating two models, one with causal indicators and another with effect indicators, does not solve the problem. The parameters of one model are not a more restrictive form of the parameters in another model. Therefore, we cannot turn to the traditional likelihood ratio test to compare their fits. Confirmatory tetrad analysis is confirmatory in that models are specified in advance. The structure of each model often implies population tetrads that should be zero. A test of a model's vanishing tetrads is a test of the model's fit.

In future research, the confirmatory strategy of Bollen and Ting (2000) can be helpful to distinguish between causal and effect indicators, but in this study it is not possible to use this method, because the construction of tetrads requires at least four observed variables (Bollen and Ting, 2000). In both of our models, the construct of real options strategy has only three indicators. Normally, when a latent variable has less than four indicators, you could use one indicator from another latent variable to evaluate whether we have causal or effect indicators. However, in this study no other latent variable on the same level as the construct real options strategy is available and therefore more research is necessary on this topic. We can conclude that we use the fit indices mentioned in previous paragraphs and the literature base to make a distinction between a formative and reflective way of modeling the concept of real options strategy.

5.5 Results of real options strategy as a second-order construct

Considering the three factor model as a base for the analysis of real options strategy as a second-order construct, we can suggest that real options strategy consists of three dimensions, the option to defer/learn, the option to invest/grow, and the option to disinvest/shrink (Copeland and Keenan, 1998).

In this part, the results of both the reflective way and formative way of modeling the construct real options strategy are presented. As argued by Coltman et al. (2008), in a reflective model the underlying construct drives the indicators, which have positive and, desirable, high intercorrelations. Contrary, in formative models indicators have no preconceived pattern of intercorrelation and they do not necessarily share the same theme (Diamantopoulos et al., 2007). In formative models, indicators can theoretically possess no intercorrelation or high or low intercorrelation. However, results of the factor correlation analysis show that there is some correlation among the different option types no hard judgment about the formative or reflective way of modeling can be made only based on the factor correlation matrix (table 5.4).

Therefore, in the confirmative analysis, two models are proposed. First, the reflective way and second the formative way of modeling the construct of real options strategy. LISREL 8.8 was used based on the raw survey file as input.
In both analyses, the measurement model seems to be significant and the results of the fit indices are presented in the following table:

Model	Chi-square	P-value	DoF	RMSEA	GFI	AGFI	PGFI	NNFI	CFI
2 (Formative model)	34.35	0.045	22	0.065	0.94	0.88	0.46	0.93	0.96
3 (Reflective model)	34.73	0.055	23	0.061	0.94	0.89	0.48	0.93	0.96

Table 5.7: Formative versus reflective model (fit indices)

Because all fit indices are close to each other, this table gives no decisive answer about the question whether to choose for a formative way or reflective way. Because a tetrad test is not possible, we need to make a choice based on theoretical grounds.
In this study, we choose for modeling the construct real options strategy in a formative way. In this way, the construct real options strategy is conceptualized as a composition of its parts (Diamantopoulos and Winklhofer, 2001; Jarvis et al., 2003). First, the direction of causality runs from the items to the construct, such that the option types will form the real options strategy construct. Second, certain dimensions of real options strategy are independent of others, based on the factor correlation matrix. E.g. the option to disinvest/shrink and the option to invest/grow seen to have no correlation. Third, covariance is possible but not necessary between the dimensions of real options strategy; in other words, a change in one indicator does not mean a change in others. Fourth, real options strategy indicators might have different antecedents and consequences with respect to the nomological net.
In terms of dimensionality, real options strategy represents a multidimensional construct with three dimensions, each of which includes a various facet of real options strategy that might indicate separate constructs but also represents integral parts of real options strategy at a more abstract level. Therefore, real options strategy becomes a function of different option types, namely the option to defer/learn, the option to invest/grow, and the option to disinvest/shrink (based on Copeland and Keenan, 1998). The following paragraph will present the analysis and results of the final research question.

5.6 The influence of Real Options Strategy on Performance

This paragraph focuses on the final sub question. The influence of the different option types on a new technology venture's performance has never been empirical investigated. It has some practical implications for managers when more knowledge is gathered on this issue. To get more insight in the influence of the option types on performance, we need to define a construct Performance which consists of the objective performance indicators OP1-OP5. Therefore, we can define this construct as the objective performance of a new technology venture. Managers were asked to provide best estimates for the following objective performance indicators:

OP1: Annual revenues in the last fiscal year ($)
OP2: The return on investment in the last fiscal year (%)

OP3: Market share in your primary served market (%)
OP4: Customer retention rate in your primary served market (%)
OP5: The rate of sales growth in the last fiscal year

These objective indicators will define the construct Performance. Because in previous paragraphs we have suggested that the most appropriate model is the formative way of modeling the construct of real options strategy, we add the construct Performance to the formative second-order measurement model of real options strategy. We can come up with the following conceptual path diagram.

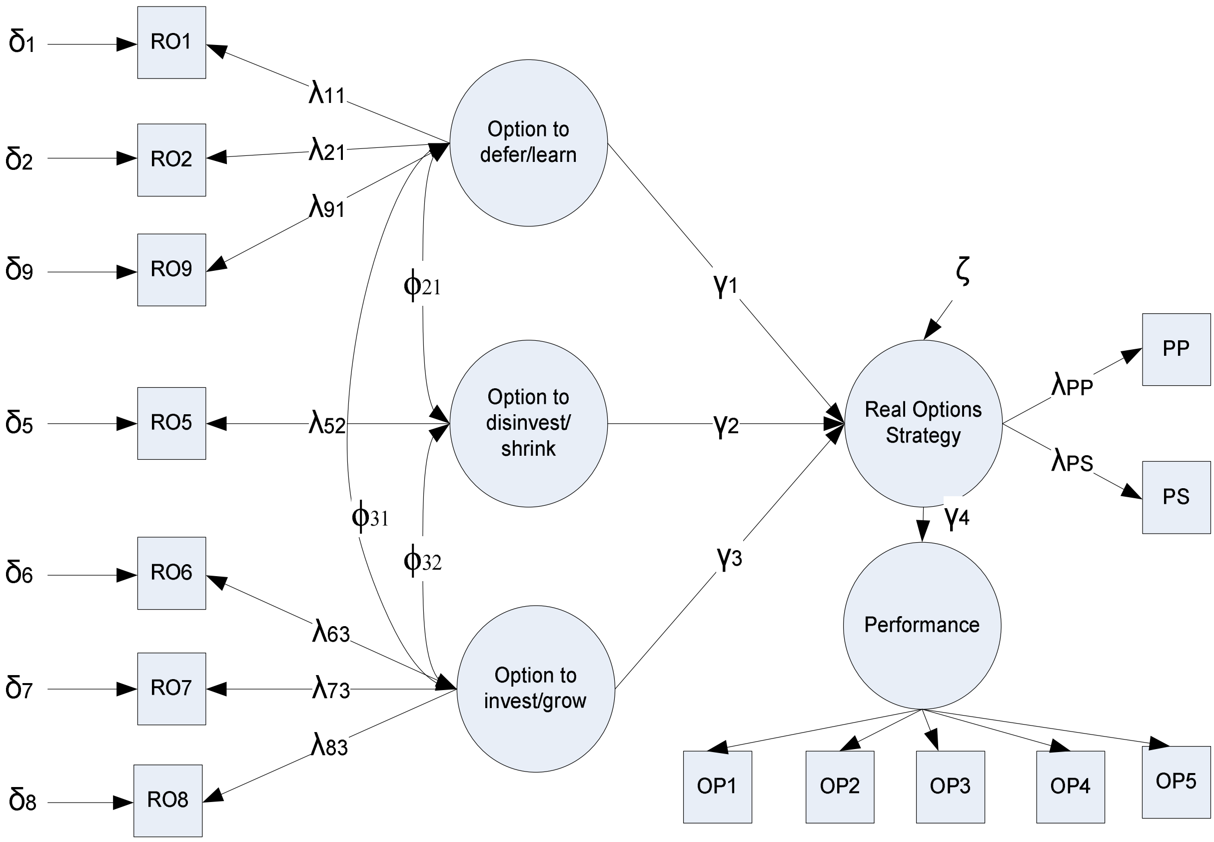

Figure 5.7: The concept of the performance model

Analysis

First, data used in this analysis need to be analyzed. Missing data, outliers, and statistical characteristics of the data need to be checked. Therefore, a series of data examination techniques are used to check the data. A normality check shows that only OP1 has no normal distribution, but a ln-transformation results in approximately normality. After these checks, a complete dataset was available with 123 cases that can be used in our analysis. This analysis is done by LISREL 8.8. Input files are presented in Appendix F and the results will be presented in this paragraph.

Results

All indicators OP1-OP5 are significant indicators of the construct Performance (t-values not between -1.96 and 1.96). This will result in a fully described construct. Looking at the t-values of

the paths in this model (see Appendix F), we can see that there is a significant relationship between the construct real options strategy and the construct performance (t-value = 2.26), but we cannot give an answer on the influence of the different option types on a new technology venture's performance.
In literature, some authors do suggestions about this relationship. For example, Amram and Kulatilaka (1999) argue that real options theory, by encouraging managers to think of decisions as carrying with them embedded options, can produce more effective strategies and achieve a higher performance. In addition, Ford et al. (2004) argue that the result of real options strategy is two-sided. First in the short term, projects improve because real options lead to greater focus on objectives, a greater focus on multiple futures, continuous strategy testing, and more accurate capturing of the project value. In the longer term, as firms become more comfortable with and more cognizant of the benefits of real options thinking, greater competencies are built and strategic positions are improved.
Nevertheless, no strong empirical evidence is found about the relationship between real option types and the performance of a new technology venture. This paragraph shows that we can conclude that there is an indirect relationship between the different real option types and a new technology venture's performance, but this relationship is not that large that it can be identified as significant.

5.7 Summary of the results

This research examined real options strategy as a second-order construct. In this study, analyses have taken into account only new technology ventures in which the project stopped (PS) value and project paused (PP) value are above average. After this study, we can suggest that the concept of real options strategy can best be presented as in the following figure.

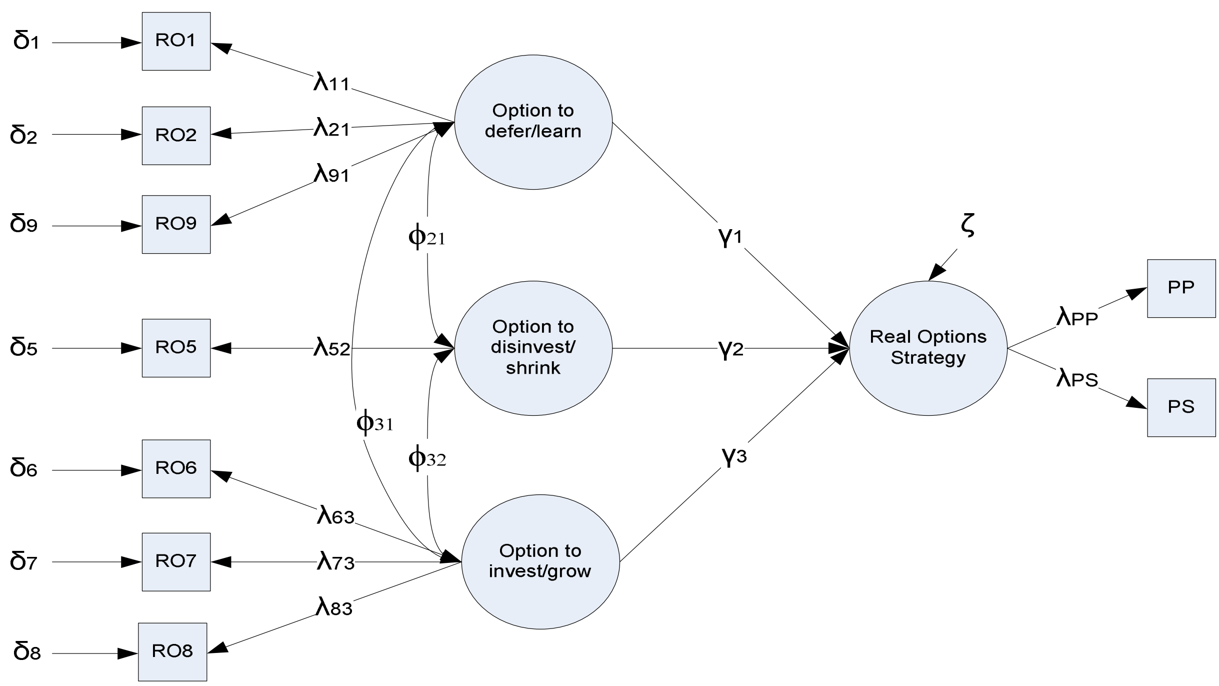

Figure 5.8: Final model of real options strategy

In this model, the classification of Copeland and Keenan (1998) and Mauboussin (1999) is used for presenting the construct real options strategy in an appropriate way. We cannot make a hard judgment about whether the different option types are correlated to each other in new technology ventures, but it seems that some correlation exists. On the fourth research question, we can answer that we propose to model real options strategy in a formative way, in which the construct is a composition of its parts.

Finally, the influence of real options strategy on a new venture's performance is investigated. On the one hand, empirical analysis shows that it is hard to make a definite judgement about this issue, but it is shown that some influence exists. On the other hand, literature shows that by encouraging managers to think of decisions as carrying with them embedded options, can produce more effective strategies and achieve a higher performance.

6 Discussion

In response to an existing gap in literature, the purpose of this study was to develop a second-order construct of real options strategy. Here, the consideration is made whether to model this construct as a formative second-order construct or as a reflective second-order construct. Through a comprehensive literature review and a quantitative study based on a survey executed with new technology ventures, this research reveals three dimensions of real options strategy, the option to defer/learn, the option to invest/grow, and the option to disinvest/shrink.

This final chapter of this report contains discussion and interpretation of the research results. First, research contributions are presented based on the research questions posed in chapter 3. The second section gives managerial implications. Third, research limitations are described after which a conclusion follows.

6.1 Research contributions

This paragraphs will be written in sequence of the research questions to be answered. A first contribution to existing research is that this study is a first empirical initiative to the model of real options strategy. Several concepts are presented in literature, but until now no empirical approach was available. The proposed approach therefore contributes to a systematic conceptualization of the dimensions of real options strategy and, in this sense, extends work by Huchzermeier and Loch (2001), Copeland and Keenan (1998), Trigeorgis (1998), Pleines (2006), and Podoynitsyna (2008), and expands the research field with an empirically based approach.

Secondly, this study provides a systematic view of the dimensions of real options strategy by operationalizing real options strategy as a second-order construct, that consists of the three different option types, the option to defer/learn, the option to invest/grow, and the option to disinvest/shrink. This way of presenting the dimensions of real options strategy is in line with the classification of Copeland and Keenan (1998).

Thirdly, an empirical stimulus is given on the issue of option correlation. The outcomes of this research do not indicate any significant correlation between different option types but they indicate that some option types are related to each other and some are excluding each other. Despite existing conceptual consideration on this issue, this study is the first that tried to found empirical results on the issue of option correlation in the classification of Copeland and Keenan (1998).

In addition, research is done whether to model the construct of real options strategy in a formative or reflective way. Because it was hard to make a consideration based on empirical results only, literature was used as added input. Considering these aspects, in this report the construct real options strategy is presented as a second-order formative construct.

Finally, some suggestions were given for the influence of real options strategy on a new technology venture's performance. A focused discussion for this issue was lacking in literature so far. This report shows that it can be suggested that there is an indirect relationship between the different real option types and a new technology venture's performance, but this relationship is not that large that it can be identified as significant.

In terms of methodology, this study demonstrates an appropriate usage of the framework of Coltman et al. (2008) to operationalize second-order constructs. Existing applications of these guidelines mostly involve unidimensional constructs; in contrast, this research defines and operationalizes real options strategy as a multidimensional, second-order construct.

6.2 Managerial implications

Although this study was focused on the added value for existing literature, the results have also some managerial implications, including guidelines for implementing real options strategy. In this study, the managers can be seen as the managers or decision makers of new technology ventures.

In this study, more knowledge is gathered on the topic of the dimensions underlying real options strategy. A classification of the different option types is derived and investigated empirically that enables managers to thoroughly take into account the main dimensions of real options strategy. In this way, managers are more aware of which option types they need to consider in defining their strategy in new technology ventures. They have a complete overview of available options and can use this in communicating their strategy.

The results also indicate the relative importance of the dimensions of the real options strategy construct regarding a new technology venture's performance. According to this study, real options strategy has a considerably influence on a new technology venture's performance, a result that seems compatible with a tendency in existing literature. In current studies (Amram and Kulatilaka, 1999; Ford et al., 2004), suggestions are done for the influence of real options strategy on a technology venture's performance. They argue that real options strategy, by encouraging managers to think of decisions as carrying with them embedded options, can produce more effective strategies and achieve a higher performance. In addition, according to them the result of real options strategy is two-sided. First in the short term, projects improve because real options lead to greater focus on objectives, a greater focus on multiple futures, continuous strategy testing, and more accurate capturing of the project value. In the longer term, as firms become more comfortable with and more cognizant of the benefits of real options thinking, greater competencies are built and strategic positions are improved.

Conclusively, it can be said that the purpose and relevance of employing real options strategy must lie in the making of improved decisions in uncertain situations. They offer managers more flexibility in decision making and therefore can be seen as a helpful tool in strategy forming. The following paragraph will present the limitations of this research.

6.3 Limitations and further research

This research started with the identification of a large gap in literature and an attempt was made to close this gap. Despite the contributions, this study contains some limitations that suggest grounds for further research. We see this paper as a step towards an empirical approach to the construct of real options strategy as a second-order model, but some limitations of this research and some issues for further research can be mentioned.

First, the assignment of the items used in the questionnaire to the different option types seems to be a rather subjective view. It seems more appropriate that this was assessed by more researchers, just to have a broader basis for these classifications. In a future study, this issue needs to be taken into account.

Second, since within the timeframe of my master thesis project it was not possible to collect real-time data, the data set provided by dr. J.D. van der Bij was the base for this research. In this data set, the sample frame consisted of venture-backed young technology firms from the VentureOne 2001 database. These were all companies in the United States and therefore, results cannot be easily generalized to other companies. Assessing the generalizability of these results could be the subject of a later study.

In addition, a clear limitation of this study for the development of general scientific conclusions is that the research was based on an existing dataset. Constructs used in the analysis were based on the relevant items in this dataset and other factors could not be taken into account.
Fourth limitation is focused on the questionnaire. In this study we used a fixed questionnaire with closed questions. In this way it is difficult to get into the problem deeply. Rather to get a more qualitative view on the concept real options strategy a study is necessary in which interviews are executed with more open-ended questions. Possibly, interesting issues will arise during these sessions.
Finally, the research focuses on real option strategy within new technology ventures. It is hard to generalize these results to corporate companies. An example is mentioned in this study and presents that the option to exist will not be used in new technology ventures, because this is suicide for the new technology ventures, while it can be a useful option in corporate companies to totally disinvest in a product option. Here, other kinds of research will be necessary focused on the difference between corporate companies. and new technology ventures.

6.4 Conclusion

This study provides insight in real options strategy as a second-order construct. Results show that this construct can best be modeled in a formative way. Empirically this was hard to judge, but based on literature a sound consideration is made. Furthermore, results show that it can be suggested that some factor correlations exist. Finally, the influence of the different real option types on a new technology venture's performance seems to exist.
Overall, the concept of real options strategy that this research presents offers an important foundation for the implementation of real options strategy in practice, as well as for further research in this field. Consequently, this study represents a next step in the path, moving to a more empirical approach of investigating the construct of real options strategy.

References

Adner, R. and Levinthal, D.A. (2004a), "What is not a real option: considering boundaries for the application of real options to business strategy", *Academy of Management Review*, Vol. 29, No. 1, pg. 74-85

Adner, R. and Levinthal, D.A. (2004b), "Reply: Real Options and Real Tradeoffs", *Academy of Management Review*, Vol. 29, No. 1, pg. 120-126

Albers, S. and Götz, O. (2006), "Messmodelle mit Konstrukten zweiter Ordnung in der betriebswirtschaftlichen Forschung", *Die Betriebswirtschaft*, Vol. 66, No 6, pg. 669-677

Amram, M. and Kulatilaka, N. (1999b), "Disciplined Decisions: Aligning Strategy with the Financial Markets", *Harvard Business Review*, Vol. 1, pg. 1-10

Bollen, K.A. (1989), "Structural equations with latent variables", *New York: Wiley*

Bollen, K.A. and Ting, K.F. (2000), "A tetrad Test for Causal Indicators", *Psychological Methods*, Vol. 5, No. 1, pg. 3-22

Borsboom, D., Mellenberg, G.J. and Heerden, J. van (2003), "The theoretical status of latent variables", *Psychological review*, Vol. 110, No. 2, pg. 203-219

Bowman, E.H. and Moskowitz, G.T., (2001), "Real Options Analysis and Strategic Decision Making", *Organization Science*, Vol. 12, No. 6, pg. 772-777

Bräutigam, J., Esche, C. and Mehler-Bicher, A. (2009), "Uncertainty as a key value driver of real options", *Working Paper*

Brosch, R. (2001), "Portfolio-aspects in real options management", *Working paper series: Finance and Accounting*

Bruun, S. and Bason, P. (2001), "Real Options approaches in venture capital finance", *Essay Series*, pg. 1-8

Chen, X. and Tokinaga, S. (2004), "Real Options with Risk Aversion Using Tradable Asset in Project Management", *Journal of Political Economy*, Vol. 70, No. 6, pg. 1-17

Coltman, T., Devinney, T.M., Midgley, D.F., and Venaik, S. (2008), "Formative versus reflective measurement models: Two applications of formative measurement", *Journal of Business research*, Vol. 61, pg. 1250-1262

Copeland, T.E. and Keenan, P.T. (1998), "How much is flexibility worth?", *The McKinsey Quarterly*, Vol.2, pg. 38-49

Curtis, R.F. and Jackson, E.F. (1962), "Multiple Indicators in Survey Research", *American Journal of Sociology*, Vol. 68, pg. 195-204

Diamantopoulos, A. and Siguaw, J.A. (2000), "Introducing LISREL: A Guide for the Uninitiated", *SAGE Publications Ltd.*

Diamantopoulos, A. and Winklhofer, H. (2001), "Index Construction with Formative Indicators: An Alternative scale Development", *Journal of Marketing Research*, Vol. 38, No. 2, pg. 269-277

Diamantopoulos, A. (2006), "The Error Term in Formative Measurement Models: Interpretations and Modelling Implications", *Journal of Modelling in Management*, Vol. 1, No.1, pg. 7-17

Diamantopoulos, A., Riefler, P. and Roth, K. (2007), "Advancing Formative Measurement Models", *University of Vienna*

Dixit, A.K. and Pindyck, P.S. (1994), "Investment under Uncertainty", *Princeton University Press*

Faulkner, T.W. (1996), "Applying 'Options Thinking' To R&D valuation", *Research Technology Management*, Vol. 39, No. 3, pg. 50-56

Folta, T.B. and O'Brien, J.P. (2002), "Entry in the presence of dueling options", *Purdue University Economics Working Papers*

Ford, D., Lander, D., and Voyer, J. (2004), "Business Strategy and Real Options in the Context of Large Engineering Projects", *Journal of Global Competitiveness*, Vol. 12, No. 1, pg. 1-9

Fornell, C. and Bookstein, F (1982), "Two Structural Equation Models: LISREL and PLS Applied to Consumer Exit-Voice Theory", *Journal of Marketing Research*, Vol. 19, pg. 440-452

Green, S.B. and Salkind, N.J. (2005), "Using SPSS for Windows and Macintosh: analyzing and understanding data, *Prentice Hall*

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., and Tatham, R.L. (2006), "Multivariate Data Analysis", *Pearson Prentice Hall,* Sixth Edition

Huchzermeier, A. and Loch, C.H. (2001), "Project Management Under Risk: Using the Real Options Approach to Evaluate Flexibility in R&D", *Management Science*, Vol. 47, No.1, pg. 85-101

Jarvis, C.B., Mackenzie, S.B., and Podsakoff, P.M. (2003), "A Critical Review of Construct Indicators and Measurement Model Misspecification in marketing and Consumer Research", *Journal of Consumer research*, Vol. 30, pg. 199-218

Jöreskog, K.G. and Sörbom, D. (1993a), “LISREL8: The SIMPLIS command language”, *Chicago: Scientific Software*

Kortner, S. (2002), “Real Options in Small Technology-Based Companies”, *Department of General and Industrial Management, Technical University of Munich*

Li, X. and Johnson, J.D. (2002), “Evaluate IT Investments Opportunities Using Real Options Theory”, *Information Resource Management Journal*, Vol. 15, No. 3, pg. 32-47

Lin, C., Sher, P. and Shih H. (2005), “Past progress and future directions in conceptualizing customer perceived value”, *International Journal of Service Industry*, Vol. 16, No. 3/4, pg. 318-336

Luehrman, T.A. (1998), “Strategy as a portfolio of real options”, *Harvard Business Review*, Vol. 76, No. 5, pg. 89-99

MacCallum, R.C. and Browne, M. (1993), “The use of causal indicators in covariance structure models: Some practical issues”, *Psychological Bulletin*, Vol. 114, pg. 541-553

Maesenaire, W. de (2006), “The real options approach to strategic capital budgeting and company valuation”, *De Boeck & Larcier*

Mauboussin, M.J. (1999), “Get Real – Using Real Option in Security Analysis”, *Frontiers in Finance*, Vol. 10 pg. 1-30

McGrath, R.G. and Boisot, M. (1998), “Corporate Level Real Options: The Strategic Equivalent to Requisite Variety”, *Paper presented at The Strategic Management Society’s annual meeting*

McGrath, R.G. (1999), “Falling Forward: Real options Reasoning and Entrepreneurial Failure”, *Academy of Management Review*, Vol. 24, No. 1, pg. 13-30

McGrath, R.G. and MacMillan, I.C. (2000), “The entrepreneurial mindset: strategies for continuously creating opportunity in an age of uncertainty”, *Harvard Business School Press*

McGrath, R.G., Ferrier, W.J. and Mendelow, A.L. (2004), “Response: real options as engines of choice and heterogeneity”, A*cademy of Management Review*, Vol. 29, No. 1, pg. 86-101

McGrath, R.G. and Nerkar, A. (2004), “Real options reasoning and a new look at the R&D investment strategies of pharmaceutical firms”, *Strategic Management Journal*, Vol. 25, pg.1-21

Mikaelian, T. (2009), An integrated Real Options Framework for model-based identification and valuation of options under uncertainty”, *Massachusetts Institute of Technology*

Miller, K.D. and Arikan, A.T. (2004), “Technology search investment: Evolutionary, option reasoning and option pricing approaches”, *Strategic Management Journal*, Vol. 25, No. 5, pg. 473-485

Muijs, D. (2004), “Doing quantitative research in education”, *Sage Publications Ltd.*

Mun, J. (2002), “Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions”, *John Wiley & Sons Inc.*

Pleines, R. (2006), “Corporate Financing by Selling R&D Option”, *Fakultät für Wirtschaftswissenschaften der Universität Fridericiana zu Karlsruhe*

Podoynitsyna, K. (2008), “Entrepreneurial risk-taking beyond bounded rationality: risk factors, cognitive biases and strategies of new technology ventures”, *Technische Universiteit Eindhoven*

Podoynitsyna, K., Song, M., Bij, H. van der, and Weggeman, M. (2009), “The effect of network externalities on the choice of uncertainty management strategies on new technology ventures”, *Working Paper*

Raykov, T. and Marcoulides, G.A. (2000), “A First Course in Structural Equation Modeling”, *Lawrence Erlbaum Associates, Publishers*

Roemer, E. (2004), “Real Options and the Theory of the Firm”, *8th Annual International Real Options Conference, CIRANO, Montreal, Canada*

Sadowski, B. (2007), “New Perspectives on Real Options Theory for Policy Analysis”, *Publication in the Series Reflectie op Electronische Communicatie*

Schryver, T. de, and Asselbergh, G. (2003), “The dynamics of real options thinking on competition through innovation: the case of the pharmaceutical industry”, C*ompetitiveness Review*, Vol. 13, No. 2, pg. 16-27

Schumacker, R.E. and Lomax, R.G. (2004), “A Beginner’s Guide to Structural Equation Modeling”, *Lawrence Erlbaum Associates Publishers*

Shah, S.K., and Corly, K.G. (2006), “Building Better Theory by Bridging the Quantitative-Qualitative Divide”, *Journal of Management Studies*, Vol. 43, No. 8, pg. 1821-1835

Spearman, C. and Holzinger, K. (1924), “The sampling error in the theory of two factors”, *British Journal of Psychology*, Vol. 15, pg. 17-19

Temme, D. (2006), “Die Spezifikation und Identifikation formativer Messmodelle der Marketingforschung in Kovarianzstrukturanalysen”, *Marketing ZFP*, Vol. 28, No. 3, pg. 183-209

Trigeorgis, L. (1993), "The Nature of option Interactions and the Valuation of Investment with multiple Real options", *Journal of Financial and Quantitative Analysis*, Vol. 28, No. 1, pg. 1-20

Trigeorgis, L. (1998), "Real Options: Managerial Flexibility and Strategy in Resource Allocation", *The MIT Press*

Trochim, W. (2007), "http://www.socialresearchmethods.net/kb/index.php" Visited on 31th March 2009

Appendix A: A Survey on Entrepreneurial Risk Management Strategies

This appendix presents a part of the survey of Podoynitsyna (2008). Here, only the questions that are used in this study will be given.

General Instructions:
This survey contains statements which may or may not apply to you. For each statement circle the answer that best represents your opinion. Please rely on your first impressions and work rapidly. Please make sure that your answer is in the correct box or number. If you cannot answer any specific questions for any reasons, please try to give your best judgment and proceed to the next question.

Confidentiality:
All responses will be held in the strictest confidence. Data will only be analyzed at the aggregate level. No individual responses will be released or disclosed. No one except the principal academic researchers will have access to the raw data.

SECTION 1. Strategies and characteristics of your firm

A. Below we list some strategies and firm characteristics. Please rate the statements on a scale of 1 to 7 that best represents your degree of disagreement or agreement (where 1=Strongly Disagree; 4=Neutral; 7=Strongly Agree; and numbers between 1 and 7 represent the varying degrees).

1. RO4: We intentionally develop our products in such a way that we can easily alter them if customer preferences change

2. RO1: If there are a lot of uncertainties surrounding a new product, we always delay developing it until we get more information

3. RO6: We intentionally develop our products in such a way that we could easily introduce new related products if our competitors start threatening our market share

4. RO3: When developing a new product, we always make sure that we can expand the scale of the project if market conditions turn out to be more favorable than expected

5. RO5: We intentionally develop our products in such a way that we can easily switch between different customer groups

6. RO9: When developing new products, we try to keep our technological design options open until we have enough information to make a choice

7. RO7: We intentionally develop technology for our products in such a way that it can easily accommodate changes in industry standards

8. RO8: We intentionally develop our products in such a way that they can be easily adapted to use a different technology, should the current one become out-dated

9. RO2: We invest in new products in stages to allow management to decide whether or not to proceed with the projects based on newest information available

B. Please rate the following characteristics of your firm and its market:

1. PP: Among all the new product development projects initiated by your firm, what is the percentage of the projects that your firm temporarily pauses the development in order to get new information? ______________%

2. PS. Among all the new product development projects initiated by your firm, what is the percentage of the projects that your firm completely stops? ______________%

SECTION 2. Performance of your firm

A. Please provide your best estimates for the following information about your firm:

- OP1: Annual revenues in the last fiscal year ($)
- OP2: The return on investment in the last fiscal year (%)
- OP3: Market share in your primary served market (%)
- OP4: Customer retention rate in your primary served market (%)
- OP5: The rate of sales growth in the last fiscal year (%)

Appendix B: Confirmatory Three Factor Analysis

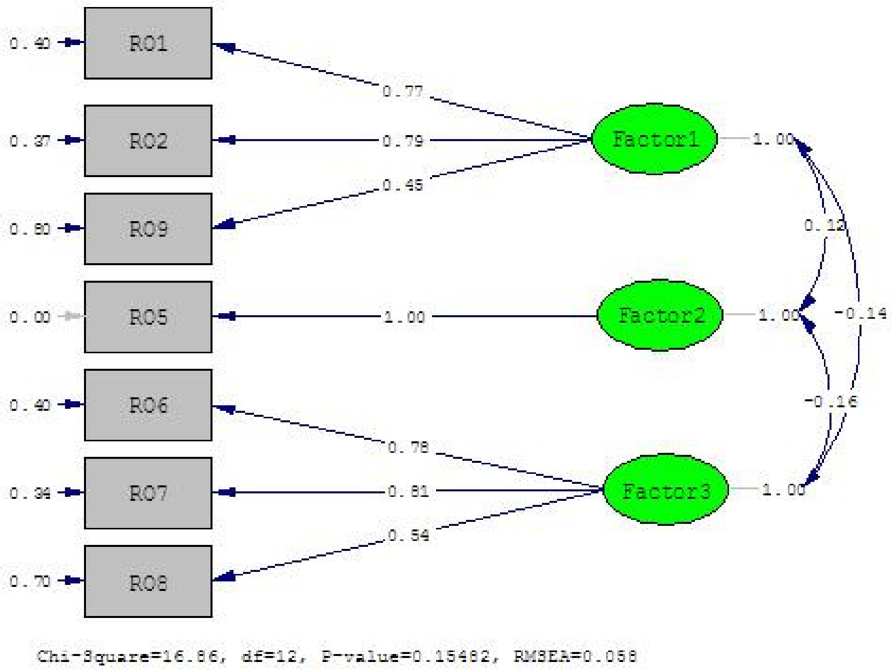

Figure B1: Standardized solution of the path diagram as produced by LISREL 8.80 student version (model 1)

Degrees of Freedom = 12 Minimum Fit Function Chi-Square = 16.91 (P = 0.15) Normal Theory Weighted Least Squares Chi-Square = 16.86 (P = 0.15) Estimated Non-centrality Parameter (NCP) = 4.86 90 Percent Confidence Interval for NCP = (0.0 ; 19.87) Minimum Fit Function Value = 0.14 Population Discrepancy Function Value (F0) = 0.04 90 Percent Confidence Interval for F0 = (0.0 ; 0.16) Root Mean Square Error of Approximation (RMSEA) = 0.058 90 Percent Confidence Interval for RMSEA = (0.0 ; 0.12) P-Value for Test of Close Fit (RMSEA < 0.05) = 0.38 Expected Cross-Validation Index (ECVI) = 0.40 90 Percent Confidence Interval for ECVI = (0.36 ; 0.52) ECVI for Saturated Model = 0.46 ECVI for Independence Model = 1.68 Chi-Square for Independence Model with 21 Degrees of Freedom = 190.50 Independence AIC = 204.50 Model AIC = 48.86 Saturated AIC = 56.00 Independence CAIC = 231.18 Model CAIC = 109.86 Saturated CAIC = 162.74 Normed Fit Index (NFI) = 0.91 Non-Normed Fit Index (NNFI) = 0.95 Parsimony Normed Fit Index (PNFI) = 0.52 Comparative Fit Index (CFI) = 0.97 Incremental Fit Index (IFI) = 0.97 Relative Fit Index (RFI) = 0.84 Critical N (CN) = 190.11 Root Mean Square Residual (RMR) = 0.083 Standardized RMR = 0.051 Goodness of Fit Index (GFI) = 0.96 Adjusted Goodness of Fit Index (AGFI) = 0.91 Parsimony Goodness of Fit Index (PGFI) = 0.41

Table B1: Fit indices Three Factor Model (model1)

Appendix C: Three Factor Model with Additional Variable

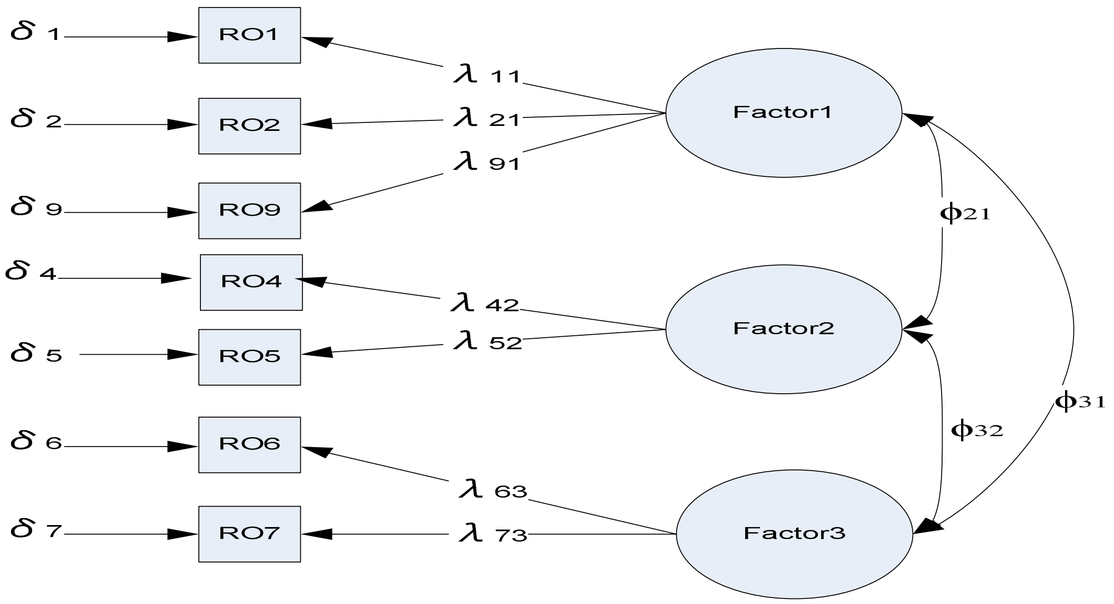

Figure C1: Conceptual three factor model with RO4

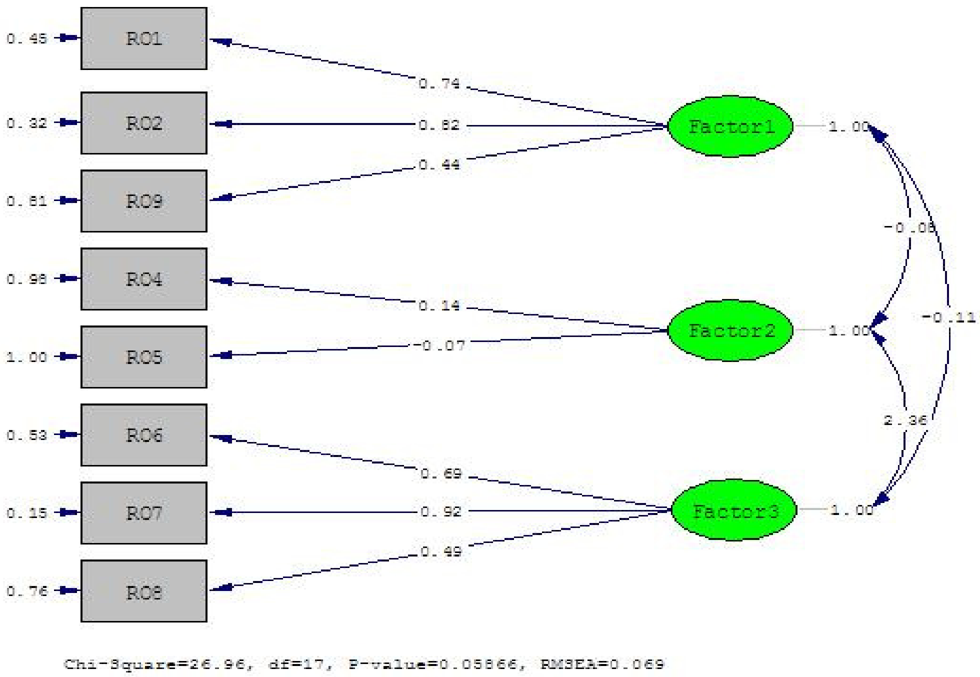

Figure C2: Standardized solution of the path diagram as produced by LISREL 8.80 student version (model 1a)

Appendix D: Formative second-order construct

```
Hypothetical Model2
Observed Variables: RO1 RO2 RO5 RO6 RO7 RO8 RO9 PP PS
raw data from file: 'C:\Users\s030364\Documents\Documents\Studie\Master Thesis\Database\database version
2.2.psf'
Sample Size: 123
Latent Variables: Factor1 Factor2 Factor3 Factor4
Relationships
Factor4 = Factor1 Factor2 Factor3
let the errors of Factor1 Factor2 Factor3 correlate
PP = 1*Factor4
PS = Factor4
RO1 = Factor1
RO2 = Factor1
RO9 = Factor1
RO5 = Factor2
RO6 = Factor3
RO7 = Factor3
RO8 = Factor3
set variance of Factor1 to 1
set variance of Factor2 to 1
set variance of Factor3 to 1
Path Diagram
Set the Error Variance of RO5 to 0.00
LISREL Output: RS MI SC EF WP
End of Problem
```

Table D1: SIMPLIS syntax of formative model (model 2)

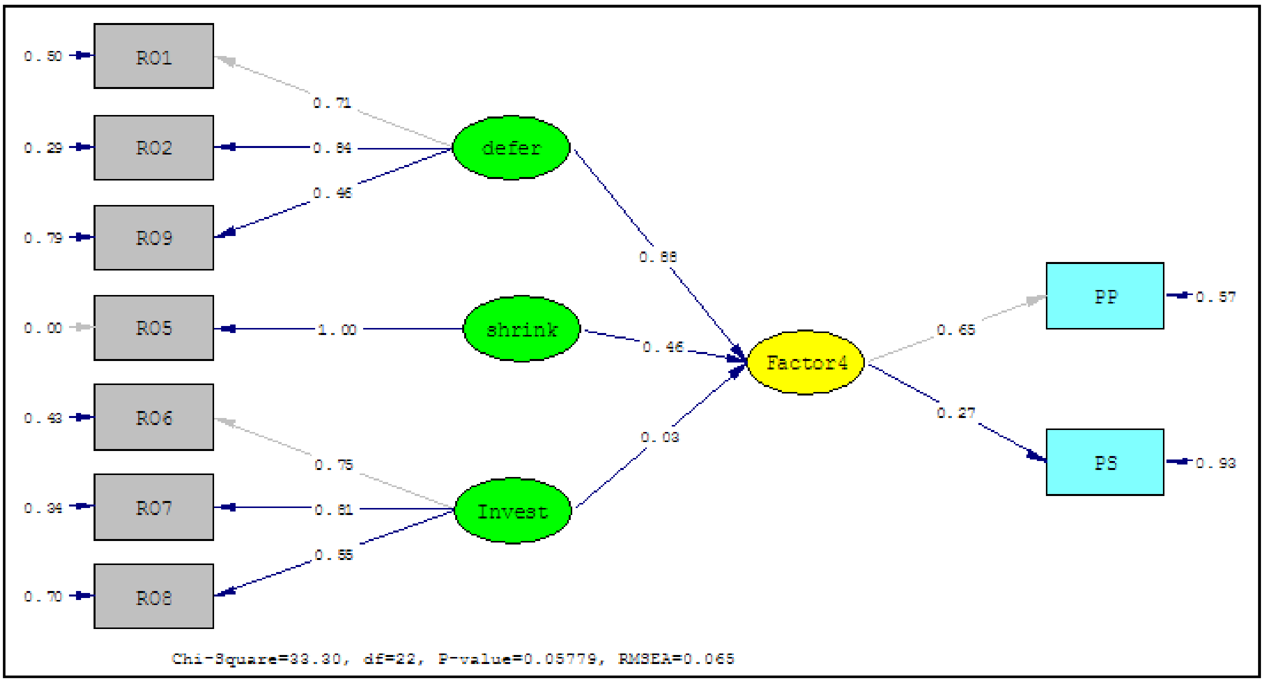

Figure D1: Standardized solution of the path diagram as produced by LISREL 8.80 student version (model 2)

Degrees of Freedom = 22 Minimum Fit Function Chi-Square = 34.35 (P = 0.045) Normal Theory Weighted Least Squares Chi-Square = 33.30 (P = 0.058) Estimated Non-centrality Parameter (NCP) = 11.30 90 Percent Confidence Interval for NCP = (0.0 ; 30.93) Minimum Fit Function Value = 0.28 Population Discrepancy Function Value (F0) = 0.093 90 Percent Confidence Interval for F0 = (0.0 ; 0.25) Root Mean Square Error of Approximation (RMSEA) = 0.065 90 Percent Confidence Interval for RMSEA = (0.0 ; 0.11) P-Value for Test of Close Fit (RMSEA < 0.05) = 0.27 Expected Cross-Validation Index (ECVI) = 0.65 90 Percent Confidence Interval for ECVI = (0.56 ; 0.81) ECVI for Saturated Model = 0.74 ECVI for Independence Model = 2.70 Chi-Square for Independence Model with 36 Degrees of Freedom = 311.43 Independence AIC = 329.43 Model AIC = 79.30 Saturated AIC = 90.00 Independence CAIC = 363.74 Model CAIC = 166.98 Saturated CAIC = 261.55 Normed Fit Index (NFI) = 0.89 Non-Normed Fit Index (NNFI) = 0.93 Parsimony Normed Fit Index (PNFI) = 0.54 Comparative Fit Index (CFI) = 0.96 Incremental Fit Index (IFI) = 0.96 Relative Fit Index (RFI) = 0.82 Critical N (CN) = 144.08 Root Mean Square Residual (RMR) = 0.52 Standardized RMR = 0.063 Goodness of Fit Index (GFI) = 0.94 Adjusted Goodness of Fit Index (AGFI) = 0.88 Parsimony Goodness of Fit Index (PGFI) = 0.46

Table D2: Fit indices Formative model (model2)

Appendix E: Reflective second-order construct

Hypothetical Model3 Observed Variables: RO1 RO2 RO5 RO6 RO7 RO8 RO9 PP PS raw data from file: 'C:\Users\s030364\Documents\Documents\Studie\Master Thesis\Database\database version 3.0.psf' Sample Size: 123 Latent Variables: Factor1 Factor2 Factor3 ROS Relationships Factor1 Factor2 Factor3 = ROS let the errors of Factor1 Factor2 Factor3 correlate PP = ROS PS = ROS RO1 = 1*Factor1 RO2 = Factor1 RO9 = Factor1 RO5 = Factor2 RO6 = 1*Factor3 RO7 = Factor3 RO8 = Factor3 Path Diagram Set the variance of ROS to 1 Set the Error Variance of RO5 to 0.00 LISREL Output: RS MI SC EF WP End of Problem

Table E1: SIMPLIS syntax of reflective model (model3)

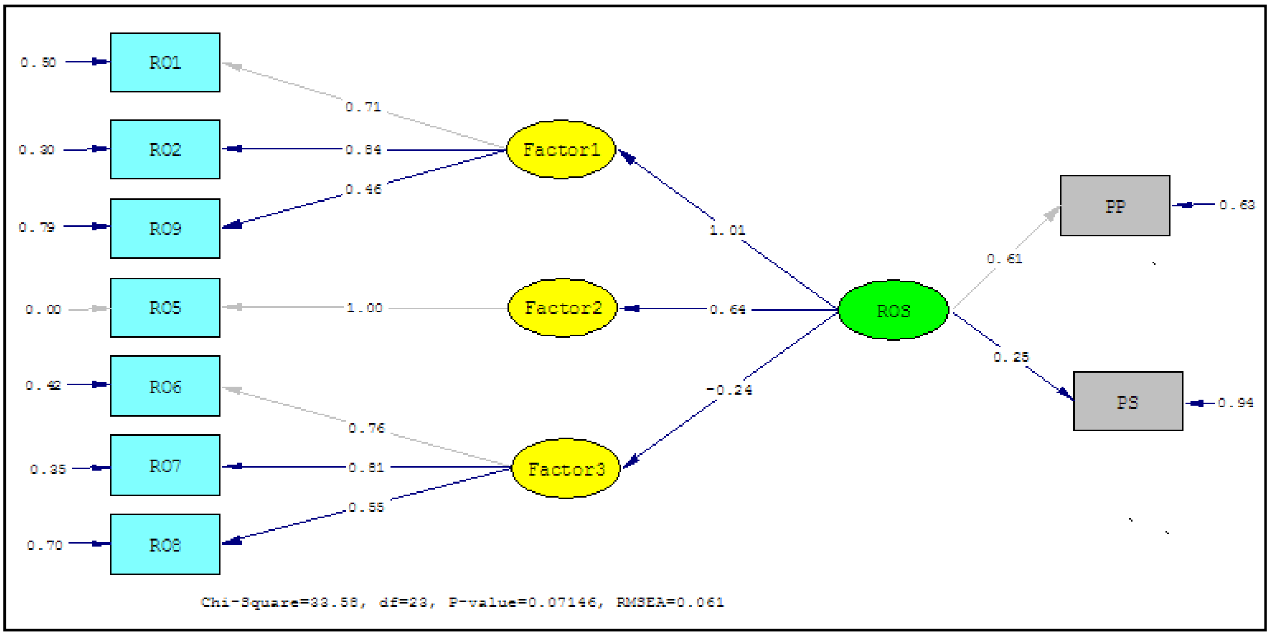

Figure E1: Standardized solution of the path diagram as produced by LISREL 8.80 student version (model 3)

Degrees of Freedom = 23
Minimum Fit Function Chi-Square = 34.73 (P = 0.055)
Normal Theory Weighted Least Squares Chi-Square = 33.58 (P = 0.071)
Estimated Non-centrality Parameter (NCP) = 10.58
90 Percent Confidence Interval for NCP = (0.0 ; 30.15)
Minimum Fit Function Value = 0.28
Population Discrepancy Function Value (F0) = 0.087
90 Percent Confidence Interval for F0 = (0.0 ; 0.25)
Root Mean Square Error of Approximation (RMSEA) = 0.061
90 Percent Confidence Interval for RMSEA = (0.0 ; 0.10)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.31
Expected Cross-Validation Index (ECVI) = 0.64
90 Percent Confidence Interval for ECVI = (0.55 ; 0.80)
ECVI for Saturated Model = 0.74
ECVI for Independence Model = 2.70
Chi-Square for Independence Model with 36 Degrees of Freedom = 311.43
Independence AIC = 329.43
Model AIC = 77.58
Saturated AIC = 90.00
Independence CAIC = 363.74
Model CAIC = 161.45
Saturated CAIC = 261.55
Normed Fit Index (NFI) = 0.89
Non-Normed Fit Index (NNFI) = 0.93
Parsimony Normed Fit Index (PNFI) = 0.57
Comparative Fit Index (CFI) = 0.96
Incremental Fit Index (IFI) = 0.96
Relative Fit Index (RFI) = 0.83
Critical N (CN) = 147.27
Root Mean Square Residual (RMR) = 0.53
Standardized RMR = 0.063
Goodness of Fit Index (GFI) = 0.94
Adjusted Goodness of Fit Index (AGFI) = 0.89
Parsimony Goodness of Fit Index (PGFI) = 0.48

Table E2: Fit Indices Reflective model (model3)

Appendix F: The Performance Model

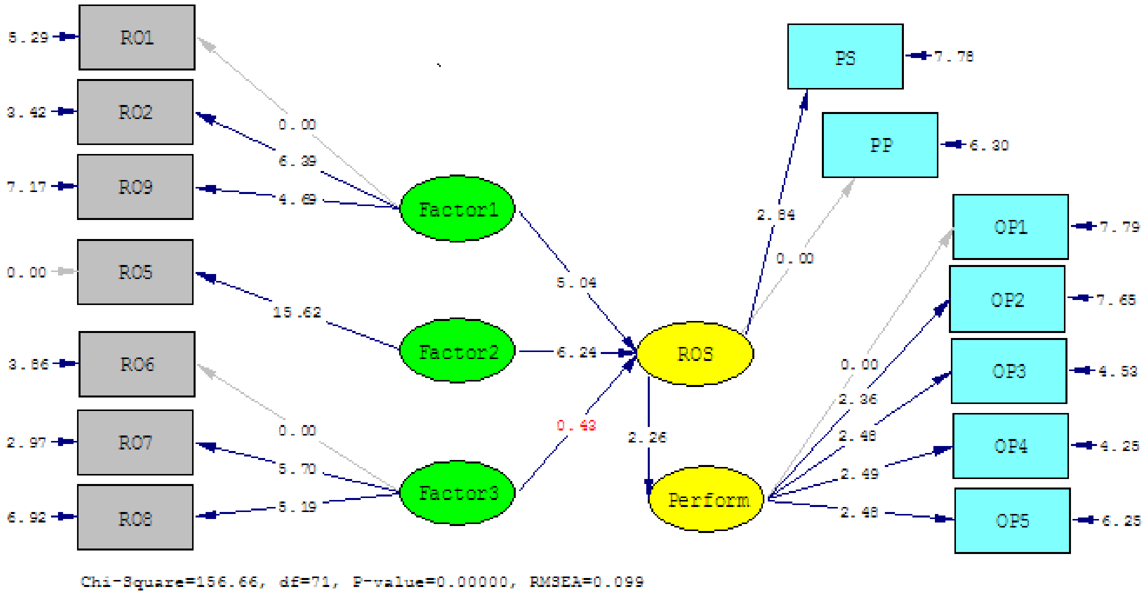

Figure F1: Path diagram with t-values of formative second-order measurement model with Performance

Formative Second-Order Model with construct Performance
Observed Variables: RO1 RO2 RO5 RO6 RO7 RO8 RO9 PP PS SP1 SP2 SP3 SP4 SP5
raw data from file: 'C:\Users\s030364\Documents\Documents\Studie\Master Thesis\Database\database version 8.1.psf'
Sample Size: 123
Latent Variables: Factor1 Factor2 Factor3 ROS Perform
Relationships
ROS = Factor1 Factor2 Factor3
Perform = ROS
OP1 OP2 OP3 OP4 OP5 = Perform
let the errors of Factor1 Factor2 Factor3 correlate
PP = 1* ROS
PS = ROS
RO1 = 1*Factor1
RO2 = Factor1
RO9 = Factor1
RO5 = Factor2
RO6 = 1*Factor3
RO7 = Factor3
RO8 = Factor3
Path Diagram tv=5
Set the Error Variance of RO5 to 0.00
LISREL Output: RS MI SC EF WP
End of Problem

Table F1: Syntax to create formative second-order model with construct performance

Goodness of Fit Statistics
Degrees of Freedom = 71
Minimum Fit Function Chi-Square = 165.94 (P = 0.00)
Normal Theory Weighted Least Squares Chi-Square = 156.66 (P = 0.00)
Estimated Non-centrality Parameter (NCP) = 85.66
90 Percent Confidence Interval for NCP = (53.26 ; 125.80)
Minimum Fit Function Value = 1.36
Population Discrepancy Function Value (F0) = 0.70
90 Percent Confidence Interval for F0 = (0.44 ; 1.03)
Root Mean Square Error of Approximation (RMSEA) = 0.099
90 Percent Confidence Interval for RMSEA = (0.078 ; 0.12)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.00016
Expected Cross-Validation Index (ECVI) = 1.84
90 Percent Confidence Interval for ECVI = (1.58 ; 2.17)
ECVI for Saturated Model = 1.72
ECVI for Independence Model = 8.28
Chi-Square for Independence Model with 91 Degrees of Freedom = 982.46
Independence AIC = 1010.46
Model AIC = 224.66
Saturated AIC = 210.00
Independence CAIC = 1063.83
Model CAIC = 354.28
Saturated CAIC = 610.28
Normed Fit Index (NFI) = 0.83
Non-Normed Fit Index (NNFI) = 0.86
Parsimony Normed Fit Index (PNFI) = 0.65
Comparative Fit Index (CFI) = 0.89
Incremental Fit Index (IFI) = 0.90
Relative Fit Index (RFI) = 0.78
Critical N (CN) = 75.72

Table F2: Fit Indices of the Performance Model