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# Supporting Deep Tech Startups to Streamline their Financial Marketing to Different Investor Types

Günther Schuh [1,2], Carolin Hamm [2]

[1]Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, Aachen, Germany
[2]Fraunhofer Institute for Production Technology IPT, Aachen, Germany

**Abstract**

Deep technology (DT) startups develop physical products based on cutting-edge technologies to create entirely new markets. Consequently, they have a comparably high demand for specialized infrastructure, expert knowledge and extended development cycles which result in large capital expenditures. However, especially early-stage (pre-seed/seed) DT startups often fail to raise sufficient funding from investors due to their large capital needs, severe technical challenges often not fully understood by investors, and long time to market. Therefore, this paper analyses the underlying issues by developing a model to support early-stage DT startups by assessing their fit with different investor types (e.g., business angels, venture capital, or other investment opportunities) in order to streamline and focus their funding process. This is achieved by applying the principal-agent-framework to model the information asymmetry between different investor types and DT startups. More than 60 relevant signals between startups and investors are derived from literature and structured in the four dimensions resources, team, sales market and technology. They are adapted to the requirements set by the signaling theory, as an approach to counteract the information asymmetry, and included into the model.

**Keywords**

Deep technology; deep tech; startups; signaling; principal-agent theory; business angels; venture capital

## 1. Introduction

The German industry is renowned for high-quality innovations and occupies the first place worldwide in science-intensive exports [1]. In contrast, the founding rate in science-intensive industries is only 3% of the total number of enterprises in this industry compared to 5% in the German economy as a whole. This puts Germany last in a European comparison and thus endangers the future of its science-intensive industries [2]. Examples like BioNTech show the potential of globally successful DT startups in Germany [3]. Securing funding and access to resources is a key factor for the success of a startup and poses challenges for both startups and investors [4–7]. However, due to the insufficient access to capital in Germany, the founding rate of technology based startups of scientific institutions is significantly too low [8]. There are two main reasons for this insufficient access to venture capital:

The first reason is that DT startups have very specific objectives and requirements within different development phases. Compared to other startups, technology driven startups are characterized by long development periods [9] and require specific expert knowledge and a corresponding infrastructure [10]. Especially later development phases are in particular capital-intensive periods when the startups are entering

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a market and building up production infrastructure [11]. Because of these named characteristics, it is essential for DT startups to find investors with compatible expectations and investment horizons.

The second reason is that founders of DT startups are usually scientists with no or little business knowledge. At the same time, investors are heterogeneous entities with a diverse motivation, focus, and investment power [12], a limited resource of time and capital to select their investment portfolio and often they do not have enough scientific background to fully understand the business idea of DT startups [4,13,5,7]. That results in an information asymmetry between startups and investors which serves as an partial explanation why DT startups receive less venture capital than other startups [14].

To alleviate these concerns, information asymmetry can be reduced by DT startups, signaling hidden investment-related characteristics to potential investors, thus helping the investor to make an informed investment decision. This paper pursues the following research question:

*"How to develop a practically appliable model which allows DT startups to identify suitable investor types and reduce the information asymmetry by making use of concrete and empirically proven signals?"*

Based on the research question, the following section selects a research design and appropriate methodology to answer the question.

## 2. Research Methodology

The present paper has the scientific aim to derive a model which helps to determine the potential fit between DT startups and different types of investors based on identified signals. Due to this strong practical orientation and its practical relevance, this work belongs to the category of applied science, according to ULRICH (see Fig. 1) [15,16].

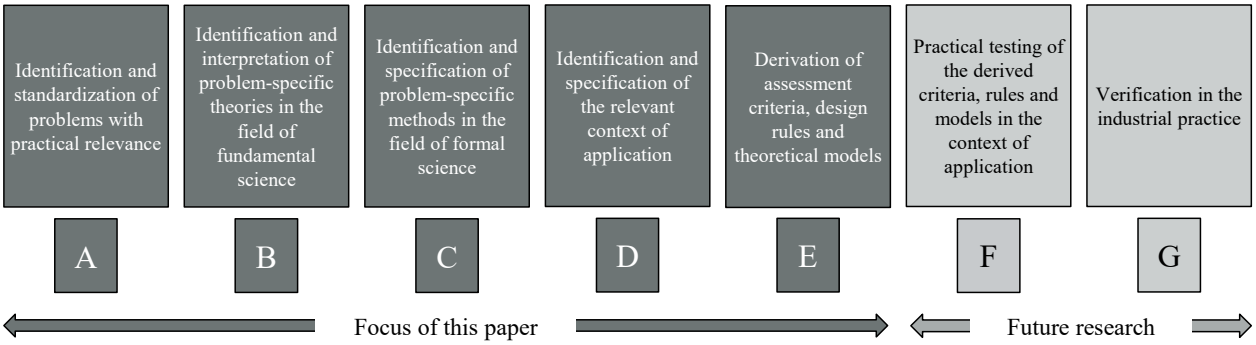


Figure 1: The methodology of applied science according to ULRICH [15,16]

The methodology of applied science by ULRICH consists of seven sequential process steps (see Figure 1). Within this paper, steps A to E are covered. In chapter 1 and 2, the initial situation, the motivation and the objective of the current paper are described, and the research methodology is introduced. Together, these chapters cover step A. Chapter 3 introduces the theoretical background of DT startups, different investors for startup financing and relevant approaches from organizational theory (step B). In chapter 4, existing approaches for determining the potential fit between DT startups and investors from literature are presented and their deficits for solving the research question are critically evaluated to determine the research needs of the present paper (step C). Chapter 5 concretizes the formal and textual requirements based on the shortcomings which are derived in chapter 4 and covers step D. Based on these specifications, the resulting model is developed and presented according to step E in chapter 6. The model summarizes the empirically proven signals from literature and therefore supporting European startups to find and attract investors with

a potential fit for their next stage of development. Chapter 7 consists of a conclusion and presents an outlook on future research topics.

## 3. Theoretical Background

The current chapter briefly introduces and defines relevant terms in the field of DT startups and investors. To begin with, the terms "DT startup" and "investor" must be defined, and their characteristics must be pointed out. In a second step, the organizational theory approaches, namely the "principal-agent-theory" and the concept of "signaling", are introduced.

### 3.1 Characteristics of DT Startups and Investors

In order to be able to extensively understand the relevant characteristics of DT startups in funding, it is necessary not only to develop an understanding of both, startups in general and DT startups in specific, but also the financing market, which DT startups can access. Therefore, a brief characterization of DT startups and investors is given.

#### 3.1.1 DT Startup

In literature, there is no generally clear definition of **startups**. The most common definition for startups is a newly founded enterprise with an innovative mindset and a high degree of innovation [17–19]. Therefore, startups possess the ability to explore new technologies and develop new business models adapted to these technologies [20,21]. This includes the ability and strong goal to scale the business model and growth [22–26]. Other characteristics of startups include an uncertain environment [27], high-risk decisions [28,29], limited funding and limited capacities in terms of human resources [22,29]. Meanwhile, the innovative power of technology oriented startups goes hand in hand with high capital requirements [17,30,31]. This contrast of high capital requirements and limited access to financial resources requires a high level of support from external institutions, which often leads to a strong dependency for a startup [17].

**Deep technology** (in short: deep tech or DT) is a term which characterizes a specific subcategory of technology. A strong reference to natural science and/or basic research in the field of engineering is characteristic for DT [32]. DT fundamentally differs from established technological applications and therefore has long development cycles and requires a high proportion of funding before it can reach market maturity [33,9,34], but also a high potential to introduce disruptive change in many industries [32,35]. In media, business and science, other terms are often used synonymously, e.g., Frontier Tech, Hard Tech, Tough Tech and Science Tech. Since the term DT is the most common and does not evoke negative or false associations, it is used in this paper [13].

The main characteristic which distinguishes so-called **DT startups** from startups in general is their focus on scientific knowledge and research which enables them to advance beyond existing technological boundaries [32,35]. The innovations driven forward by DT startups are usually disruptive, fundamental and/or they have a high transformative potential [36,37,10]. DT startups usually work in fields like artificial intelligence, blockchain, robotics, high-tech materials or drones, in industries like material science, biotechnology, manufacturing, medical technology, nanotechnology, aerospace, mobility, and energy [38,32,34,39]. With these focal points and the ability to revolutionize existing technologies, many DT startups have the potential to solve major societal and environmental problems and develop new markets [33,40]. The downside of this disruptive potential is that the risk is significantly higher than for regular startups. This risk consists not only of the technological risk of developing a fundamentally new technology to market maturity, but also of a high market risk of finding or creating a suitable sales market for this technology [41,40,42]. The absence of empirical evidence concerning the business model makes it difficult to determine a market value of DT startups. The peculiarities of DT startup financing can be derived from these specifics: DT startups require

expert knowledge and the necessary physical infrastructure for a suitable research environment [10]. It must also be taken into account that DT startups have long development cycles and require extensive funding before they can reach market maturity [33,9,34]. According to HAHN, the development of startups can be differentiated into early phase, growth phase and late phase. The early phase ends with the product launch [11]. Objective of this paper is to examine the significance of signaling in a context where none of the usual criteria which are used for the market valuation of a company are yet available and startups have difficulties demonstrating their qualities to potential investors. Therefore, this work focuses on the early phase.

#### 3.1.2 Investors for Startup Financing

A basic challenge for startups is raising necessary financial resources to fund the early phase of their development. Funding opportunities can be differentiated into debt capital, equity and mezzanine capital, which is a combination of debt capital and equity [43]. Since startups have little access to debt capital due to a lack of collateral and usually do not generate profits in the early phase, the injection of equity capital from outside is essential [44,45]. Equity investors can be differentiated into formal and informal capital. In contrast to informal capital, formal capital involves so-called financial intermediaries, e. g. venture capital funds [46,47]. Both terms are explained in the following:

**Formal equity capital** can be divided into private, corporate, and public venture capital as well as crowd investing differentiated based on the capital providers [46,48]. All types of formal equity are briefly explained below. Private venture capital investors are intermediaries between external investors like pension funds and startups [47]. The financial resources come from temporary funds. Until the end of the fund's term, the investors try to increase the value of their investments and sell their shares. [46] Corporate venture capital investors are divisions of established companies that partner with startups depending on strategic objectives. They usually offer not only financial support, but also expert knowledge and infrastructure. [47] Public venture capital investors like the German KfW are state-owned investment companies with the aim of supporting startups [49]. In crowd investing, the platform acts as a financial intermediary between the startup and a large number of small individual investors [48,50].

**Informal equity capital** can be provided by business angels, incubators, friends, and families. Business angels are wealthy private individuals with extensive founding or management experience who invest their own assets and provide their expert knowledge [51]. Incubators are service centers which provide especially infrastructure and/or consulting as well as funding [52]. Friends and families usually invest small amounts in a startup which are not tied to strict contracts [53,46].

The **collaboration** with equity investors can essentially be divided into **three phases**: selection, investment, and exit [54]. In the selection process, there are few objective criteria like early sales indicating the company's profitability [55]. The investment phase is divided into different steps and the founding rounds are tied to specific milestones [56]. As the last phase, the exit, equity investors intend to sell their shares.

From the variance of types of equity financing presented, it becomes apparent that various investor types differ in their organizational background, motivation, investment behavior, and other characteristics [53,44,46,57,47,58,48,51,49]. Startups need to implement an appropriate strategy to address investors for the next development cycle, including sending of relevant signals to the various investor types to find investors with suitable funding objectives and requirements for collaboration.

### 3.2 Organizational Theory Approaches

Organizational theory is an umbrella term under which multiple theoretical approaches dealing with organizations, their formation, and persistence can be summarized. Related to economy, organizational theory explains how collaboration between different companies can be created for a suitable way to ensure access to scarce resources. [59,60] One main difficulty in the funding process between startups and investors

is information asymmetry [14]. The principal-agent theory being one approach of the organizational theory addresses this problem [61]. In the next section the principal-agent theory is briefly introduced first, followed by an introduction of signaling as an approach to reduce this asymmetry.

### 3.2.1 Principal-Agent Theory

The principal-agent theory describes the interaction between two economic actors (principal and agent) with a specific interdependence: The principal's success depends on the agent's activities while the agent has more information than the principal. Some of this information cannot be obtained securely by the principal, e.g., the agent's motivation, other may require a high research effort [61]. This results in two typical problems between both parties: adverse selection and moral hazard. Adverse selection means that the principal does not choose the optimal agent for cooperation. Moral hazard means that the agents can be tempted to act against the principal's interests [62].

The principal-agent theory offers approaches to counteract these problems. Approaches to counteract adverse selection are signals which the agents can send to the principal to demonstrate their motivation and abilities. In the process of self-selection, the agent can be presented with various draft contracts with deviating fixed and performance-related payments. The selection made by the agent allows the principal to draw conclusions about the agent's motivation and skills. In addition, careful selection procedures can help to avoid adverse selection [63,61]. In order to counteract moral hazard, the principal can strictly monitor the agent, restrict its room for action and create incentives [61].

Since moral hazard is a problem that occurs after the financing decision, it is not further investigated here [61]. Signaling is the dominant way for the agent, in this case the startup, to identify and address potential investors with an optimal fit. It is therefore focused with this paper.

### 3.2.2 Signaling

Signaling is an effective measure for reducing information asymmetry between startup und investor (see chapter 1). It can be actively controlled by the startup acting as the transmitter of signals. The presentation of CONNELLY ET AL., which divides a signaling process into four steps, provides a good overview of the mechanism. In the first step, there is a signal transmitter with a non-public quality, e. g., a startup which has developed a disruptive technology. In the second step, the transmitter sends a signal that is intended to show this quality to the signal receiver, e.g., through a patent application. In the third step, the signal receiver receives and interprets the signal. In this case, the signal receiver can be a potential investor who evaluates this signal positively or negatively depending on the investor's own priorities and needs. In the fourth step, the signal receiver gives the signal transmitter positive or negative feedback. [64]

The concept of signaling has two advantages: Startups can actively contribute to this process by controlling the signals sent. In addition, the concept does not prescribe a specific reaction but leaves room for interpretations by the investor. In this way, it takes into account the heterogeneity of the investor landscape (see section 3.1.2). [64]

## 4. Literature Review

Existing approaches in scientific literature, various procedures, and models for supporting the initiation process for a collaboration between DT startups and investors are presented and critically reviewed. Aim of this chapter is the elaboration of problem-specific shortcomings in theory to derive requirements for the subsequent model development.

When searching for models, it is noticeable that there are few publicly accessible models regarding the suitability of investors for startups. This deficit is especially significant for DT startups, because research in this area is still fairly new. Therefore, in the first step, approaches for evaluating the suitability of investor types for startups in general are considered without a special focus on DT startups (see subchapter 4.1). In the second step, approaches for structuring the investor landscape for DT startups are evaluated to gain an overview of relevant investor types (see subchapter 4.2). In the last step, approaches for evaluating the suitability of investor types for DT startups are examined (see subchapter 4.3). The results of the review of existing approaches are summarized in subchapter 4.4, highlighting the shortcomings of the approaches.

### 4.1 Approaches for Evaluating the Suitability of Investor Types for Startups

The approach of HEINEN [65] focuses on the process of matching suitable investors to startups [55]. In the course of his research, 53 investors active in Germany were interviewed concerning their characteristics, general investment behavior, and success of their startup-investments. For comparability, generic types are developed for both startups and investors based on a literature review and supplemented by the interview results and a similarity analysis. In the model four superior types of startups and five types of investors are identified and the fit of the different types among each other is examined. The paper offers valuable insights especially concerning the characteristics of investors. However, HEINEN focusses on venture capital investors and other investor types, e. g. business angels, are not considered. Furthermore, he focusses on technology driven startups but not especially on DT startups.

TECH [66] describes the complexity of high-tech startup financing and the significance of signaling for the reduction of information asymmetry. 16 possible fields of actions for startups are identified and assigned to different signals to develop 85 matches of signals and fields of action. It is one of few works examining the importance of signaling for the German financing landscape. These country-specific insights are valuable for categorizing signals that startups can use to actively convince investors in Germany.

Based on Crunchbase data, the quantitative probability model by ZHONG ET AL. [67] recommends investors in which startups they should invest. The model considers investment preferences of investors, expected returns, and potential risks. To validate the model, the data-set is split into training and validation to show that the method can increase profits and lower risks. Even though this approach purely takes the perspective of investors, requirements for the investors can be derived for this work.

MOHAMEDALI [68] presents an own developed software tool that aspires the process of matching founders and seed investors. The own developed algorithm based optimization supports the selection process between startups and investors without using an existing database. In this way, the author could not only examine the decision criteria ex-post but also access data from the process leading there. This allows interesting inferences for the model developed in this work.

### 4.2 Approaches for Structuring the Investors for DT Startups

After models for matching investors with startups in general have been introduced, this subchapter sheds light on structuring investors with a special focus on DT startups. Currently, the research landscape offers only one suitable article.

In their paper, LAKHANI ET AL. [34] structure the investor landscape based on institutional backgrounds which are divided according to the introduction of equity and debt. They identify business angels, venture capital funds and strategic investors as types with a special focus on venture capital. Since there is no restriction to a certain stage of development in their paper, Initial Public Offerings (IPOs) are considered as a source of financing. In addition, the authors discuss the process of evaluating DT startups and conclude, that in early investment phases, the evaluation of DT startups is especially subjective due to their

characteristics. Nevertheless, valuation dimensions such as the existence of a clear business plan can be derived for this work.

### 4.3 Approaches for Evaluating the Suitability of Investor Types for DT Startups

When assessing the suitability of investor types for DT startups, one scientific article by BELZ stands out.

BELZ [69] examines the financing of DT startups via equity crowdfunding. Equity crowdfunding means that multiple private individuals invest small sums in the startups' equity. This approach shows that crowdfunding is a valid form of financing for a DT startup especially an early phase. The empiric examination shows that retail investors, non-professional investors who might participate in crowdfunding, have less stringent requirements due to their lack of financial know-how and are therefore more attractive for DT startups. Since the study was conducted in the USA, it can not necessarily be transferred to the European financing market.

There are no additional scientific papers, but exchange of experiences in forums, blogs, and podcasts by experienced investors is presented to introduce new thoughts and approaches in this field of research. Venture capital funds are considered to be investors with the necessary financial leeway, but they are criticized for their short investment horizon. So-called patient capital, which means that venture capital funds expand their investment horizon, is discussed as a possible solution [70]. Additional non-monetary services like consulting or access to networks are particularly valuable for DT startups [71].

### 4.4 Interim Summary

In conclusion, four superordinate deficits can be identified in the approaches presented in the previous sections. The specifics of DT startups are given insufficient consideration. Often, assumptions made for startups in general are uncritically adopted to DT startups. Given their characteristics, the admissibility of this takeover is questionable. A detailed focus and analysis on DT startups would be necessary to assess these assumptions. In addition, the existing approaches do not offer a detailed examination of the early phase of development which is the focus of this paper. The early phase is critical for the startups' search for investors and is characterized by the lack of fully developed business processes. An additional deficit is a research gap concerning the suitability of the investors for DT startups. This is related to the overall insufficient data for DT startups. Finally, the presented models do not provide options for action for the DT startups but represent a purely analytical or investor-centered approach. The identified weaknesses are subsequently addressed and a systematized approach of using signalling to reduces information asymmetry between startups and investors is presented in the following chapters.

## 5. Derivation of Requirements

Based on the shortcomings determined in chapter 4, the requirements for the model to reduce information asymmetry between startups and investors by making use of signaling must be specified. Requirements can be divided into formal and textual requirements. They serve as a framework with concrete objectives and help to develop and validate the model. Based on these objectives and the practical and theoretical shortcomings, the superordinate model requirements are derived.

### 5.1 Formal Requirements

The formal requirements aim to ensure a high formal model quality. They are oriented on the model-theoretical principles by PATZAK [72]. According to PATZAK, a model shall be formally true, productive, manageable, and not too complicated. To meet these requirements, the model must be validated with

practical examples, it must be appropriately adapted to the exact requirements, easy to handle and a positive net benefit must be ensured.

### 5.2 Textual Requirements

The model aims to enable DT startups to evaluate the relevant characteristics of investors for a potential cooperation. Three textual requirements follow from that: the characteristics of DT startups must be considered, the involvement of different types of investors must be ensured, and the preparation of matchmaking between DT startups and investors must be considered.

As DT startups are the central research element, the differentiation of the exact *requirements and needs of DT startups is essential*. To be able to capture the current state of the own company, a structured analysis of its own is necessary due to the diversity of needs in terms of competencies and resources associated with the different development phases. Based on that, a first rough selection of suitable investors or required fields of action can be determined.

DT startups searching for investors usually lack an *overview of the potential candidates and their requirements*. Therefore, the model must broadly describe the potential equity investors. This creates transparency and enables DT startups to determine their own potential fit with investors. Unsuitable investors can be excluded at an early stage to minimize the effort.

In order to show the *suitability between DT startup and investors*, properties of the DT startup and the investors with their requirements *must be linked*. Based on this comparison, the DT startup being the model's user shall be able to preselect investor types that might be suitable for a cooperation. By doing so, the limited resources of a startup can be focused on proactively addressing these investors and sending them the appropriate signals.

## 6. Results

In the following, the model structure for the reduction of information asymmetry between startups and investors by using the signaling theory is conceptualized. This marks step E in the research process of applied sciences by ULRICH (see chapter 2).

### 6.1 Derivation of Model Structure

After both formal and textual requirements have been formulated, the model can be derived based on the theoretical fundamentals (see chapter 3) and on the analysis of the existing approaches (see chapter 4). According to the textual requirement for a systematic outline of characteristics and needs that must be covered for a DT startup, the model characteristics of DT startups must be systemized with a focus on specifications of the early investment phase (see section 6.2.1) in the first step. In addition, the deficit of an insufficient overview for DT startups for relevant investors was identified and defined as a requirement for the model. For a more detailed view of LAKHANI ET AL. [34] existing investor structuring, the model needs to structure the DT investor landscape based on type specific features (see section 6.2.2) in the second step. Both the systematization of the characteristics of DT startups and the structuring of the investor landscape contribute to a reduction of complexity in order to enable a practical evaluation. Furthermore, the requirement to link characteristics of a DT startup and investors is meant to show the fit between both parties. Following TECH [66], identified signals are assigned to evaluation dimensions. This is achieved with the third step to assign investment-relevant signals to both valuation dimensions and investor types to create specific signal profiles for potential collaborations (see section 6.2.3). For this purpose, relevant signals for DT startups are collected through a detailed literature review. In order to finally link investor as well as DT start-up signals as well as characteristics a fourth model is required, which assesses the suitability of investor

and start-up combinations (see section 6.2.4). The structure in four steps is visualized in Figure 2 and the four submodels are further designed and concretized in section 6.2.

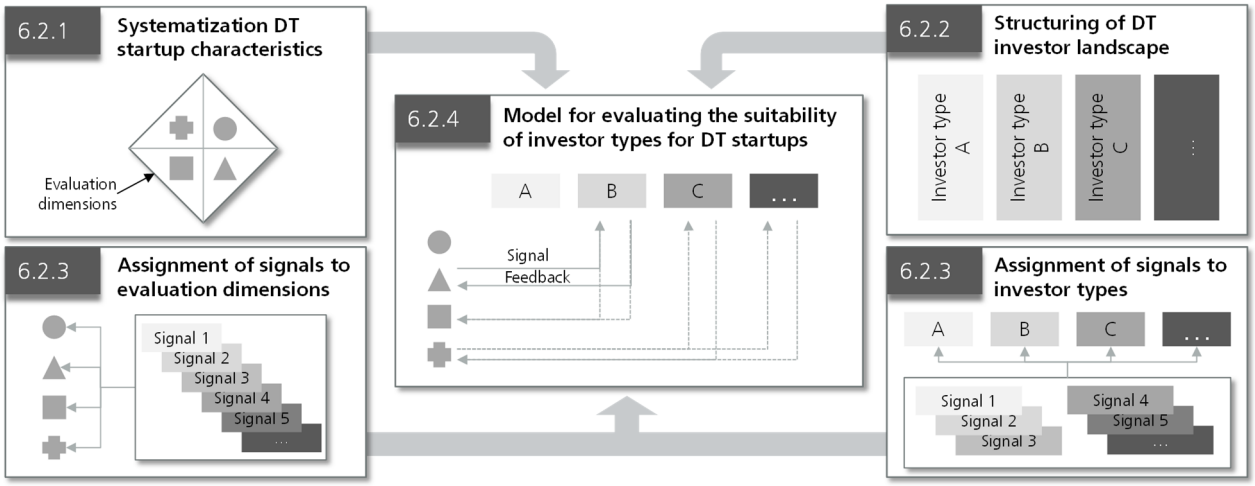


Figure 2: Model structure consisting of four submodels

## 6.2 Characterization of Submodels

### 6.2.1 Systematization of Characteristics of DT Startups

The evaluation of startups in the early phase is challenging [55], mainly due to the lack of financing history and in connection with complex technical products of DT startups. Therefore, classical evaluation methods, such as the discounted cash flow method, often cannot be applied [73]. However, a field study by SCOTT ET AL. showed that investors were comparatively good at estimating a startup's probability of success when concrete scientific findings are available [74]. Depending on the investor type, the focus of the valuation of a startup differs. Within this work, a differentiation is made between four different types of investors (detailed in section 6.2.2). While *private venture capital* funds focus on technology and competitive situation, *business angels* value personal factors like education and personality higher [12]. *Corporate venture capital* funds focus on the strategic fit between the parent company and the startup, but their assessment procedures are poorly researched [75]. There is also a large research deficit for *crowd investing*.

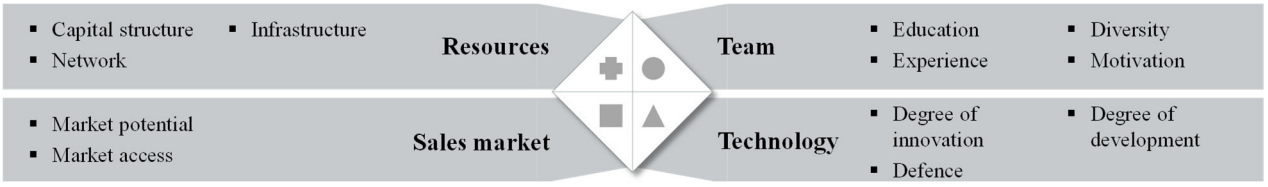


Figure 3: Overview of evaluation dimensions for DT startups

Across all investor types, four general valuation dimensions can be determined (see Figure 3). In the early phase, startups rely primarily on the behavior and the decision of the *founding team*, so its experience [76–78], formal education [79], motivation [76,77] and diversity of abilities, gender and age are relevant information [77,78]. The second dimension consists of the developed product or service, which are summarized under the term of *technology*. On the one hand, the degree of innovation helps to assess the potential of the technology and the associated risk [80]. On the other hand, the degree of development helps to assess whether the startup is able to successfully establish a new technology [81]. Furthermore, the defense of intellectual property is important to evaluate whether competitors can endanger the startups competitive position [82]. The third dimension concerns the *sales market*. Both market size and market growth are important signals to evaluate market potential for a new technology [80,76,78]. Additionally, investors

mostly prefer industries that correspond to their own specialization [78], as this allows them a better understanding for evaluation. Access to *resources* is essential for the further development and long-term success of a startup, which is therefore also a relevant valuation dimension, particularly from the perspective of investors. Main resources are the capital structure with equity and debt [83,77], the quality and size of the startups network [78], and its infrastructure, e. g., workspace, production capacities, or test capacities [82]. Following, these four dimensions are used for structuring and evaluating the investment-relevant signals.

### 6.2.2 Structuring of DT Investor Landscape

Based on the results of the literature research on existing equity financing options for startups (see section 3.1.2), the relevant equity investor types can be differentiated into private venture capital, public venture capital, corporate venture capital, crowd-investors, business angels, incubators, as well as families and friends. The objective of this paper focuses primarily on organizational investors who can support the necessary needs and resources for a DT startups organizational development. According to the scope of this work, public venture capital, incubators, and families and friends are excluded from further consideration. Public venture capital funds typically only invest jointly with Private venture capital funds, which are already focused. As Incubators are service centers which primarily provide infrastructure and/or consulting they do not primarily invest financial capital [84] and are therefore excluded. Investments by families and friends are usually small and not tied to strict contracts but based on a relationship of trust [46].

To structure the heterogeneous investor landscape with relevance for DT startups, different types of investors are worked out based on differentiating characteristics. For identifying these characteristics, the approaches by GUGGEMOOS, SORHEIM AND LANDSTRÖM and RIFFELMACHER are used: GUGGEMOOS discusses venture capital funds and identifies six typifying characteristics: sectoral affiliation, objectives of the investment strategy, scope of management support offered, geographic orientation, ownership structure and investment focus [85]. Besides this, SORHEIM AND LANDSTRÖM identify two type-building characteristics based on the objectives of the investment strategy: investment activity and investment competence [86]. RIFFELMACHER uses similar characteristics: investment activity and financial and business background [51] as typifying characteristics. The consideration of the three approaches shows that the differentiation of investor types can be done based on different type-building characteristics. According to the authors, there is no consistent use of type-building characteristics for the different equity financing types. Therefore, no further classification of the previously presented equity investors is carried out for this work.

### 6.2.3 Assignment of Signals to Evaluation Dimensions and Investor Types

After deriving the dimensions for classification and clustering of relevant signals in the previous models, a detailed literature review concerning empirically researched signals is necessary to identify possible signals. The databases used are RWTH's own database KATALOG, general scientific databases such as ScienceDirect and Wiley Online Library, and economic databases like Business Source Premier, EconLit and OLC Wirtschaftswissenschaften. For the research, the key terms "signal", "startup" and "entrepreneur" are especially used. Only renowned journals with A+, A or B rating are considered. In this way, 186 articles are identified. These articles are reviewed in detail to ensure that the content is consistent with the objectives of this work. Thus, 44 sources were selected for detailed analysis and searched for investment-relevant signals according to the identified valuation dimensions and investor types. In this way, a total number of 108 signals is identified. A complete table of all signals found, broken down by evaluation dimensions and investor types, is given in the appendix (see table 1 and table 2). The procedure is illustrated using a group of sample signals in the following (see figure 4).

| Evaluation dimension | Subdimension | Signal |
|---|---|---|
| Team | Education | Level of education [58]:<br>• Technical education [94]<br>• University degree [58,89,90]<br>• Dissertation [58,90]<br>• MBA [91,92]<br>• Professorship [89,95] |

Extract table 1

*Allocation of signals with a relevance for the investor types*

| Evaluation dimension | Subdimension | Private Venture Capital | Business Angels | Crowd-Investors |
|---|---|---|---|---|
| Team | Education | Level of education:<br>• Technical education<br>• University degree<br>• Dissertation<br>• Professorship | *No allocation of signal relevance to be derived from the literature* | Level of education<br>• Dissertation<br>• MBA |

Extract table 2

Figure 4: Extract table 1 and 2 (see appendix) showing the signal allocation to evaluation dimensions and investor types

The first evaluation dimension is "team" with "education" as one subdimension. Consistent with the assumed importance of the team for investment decisions, some signals concerning the education are identified which strongly influence the reaction of investors in literature [53,87,88,79]. To give an example, teams can signal quality through achieved university degrees [89,58,90] and through successfully completed MBAs [91,92]. The educational qualifications have a greater effect if these qualifications were obtained at renowned universities [93]. In science-related industries, a large variety of different technical abilities in a team is important [94]. Analogously, further signals for the further evaluation dimensions and subdimensions are identified and detailed (see appendix table 1).

In a second step, investor-specific differences are determined to allow DT startups a specific addressing of suitable investor types to reduce information asymmetry. The literature review does not provide any signals concerning corporate venture capital, as there are currently no research results that can be used as a basis by analogy. Therefore, corporate venture capital cannot be considered further. The effect of signals on the different types of investors is carried out as an example for "education". Public venture capital funds value schoolings [94], university degrees [58], dissertations [58,90], and professorships [89,95]. Renowned universities increase the effect of these signals [93]. For business angels, no signals of the subdimension education could be identified in the literature. However, it must be noted that generally fewer signals were identified for business angels than for public venture capital. Furthermore, crowd investors value dissertations [58,90] and MBA-certificates [91,92]. Dissertations and professorships were also mentioned as relevant education signals for investors without being assigned to a specific investor type. Further assignment of signals to investor types within the evaluation dimensions and subdimensions is shown in appendix table 2.

### 6.2.4 Model for Evaluating the Suitability of Investor Types for DT Startups

The research results of signals detected for the different investor types in literature are summarized in tabular form in the appendix (extract see figure 4). Table 1 presents the entity of the signals subdivided into the different evaluation dimensions and subdimensions. Across the assessment dimensions, a large number of different signals could be identified for DT startups. The largest number of signals could be assigned to the valuation category "team" which emphasizes the striking importance of the team for the early phase of DT startups. Many signals could also be assigned to the category's "technology" and "resources". For the category "sales market" only 12 signals are identified. A similarly heterogeneous picture can be seen in the assignment of the signals to the investor types (see appendix table 2). For corporate venture capital, no specific signals could be identified while many signals could be assigned to private venture capital. A similar number of signals could be assigned to business angels and to crowd investors. This results in a specific signal profile for each investor type. By matching the valuation dimensions and the assigned signals with their own business, DT startups can determine their specific signal profile using table 1 which can be

compared to the investor-specific signal profiles with the help of table 2. In this way, DT startups can analyze which types of investors may be suitable for their specific situation and which signals they should systematically send in order to attract these investors. It should be taken into account that a clear separation of signals to investor types cannot be unambiguously guaranteed based on the findings in literature. In summary, the model enables the assessment of the suitability of startups for the different investor types.

## 7. Conclusion and Future Research

The goal of this paper was the development of a model which allows DT startups to identify suitable investor types and reduce the information asymmetry by making use of concrete and empirically proven signals based on a detailed literature review. Chapter 1 and 2 introduced the topic and the research methodology. In chapter 3, the scope of investigation was determined, characteristics of startups in general and DT startups were worked out with a focus on the early phase of development. The general financing options for DT startups were explained and equity investors were discussed. Regarding organizational theory an introduction to principal-agent theory was given. Based on the identified practical deficit in DT startup financing, in chapter 4, existing approaches to support the initiation process for a collaboration between DT startups and investors were reviewed and a theoretical deficit was identified in the examination of DT startups. Chapter 5 derived the textual and formal requirements. In chapter 6, the model structure with four submodels was developed based on these requirements. First, evaluation categories of startups for investors were derived. Then, different types of investors were categorized as appropriate for equity financing of DT startups. For the third and fourth submodels, an extensive literature research was conducted to identify 104 signals helping to reduce information asymmetry which were assigned to both the evaluation dimensions and the investor types. The resulting structure provides a transparent overview and serves as a practical orientation for DT startups when reaching out for potential investors for a cooperation.

However, the classification of signals conducted in this paper is not sharply defined. Many of the signals are ambiguous, e.g. oppositions in patent proceedings show the innovative potential of a startup and simultaneously endanger the startup's market position. In this regard, it should be emphasized that this paper shows the current state of scientific knowledge, which is still incomplete e.g., with regard to CVC. It should be taken into account, that a clear separation of signals to investor types cannot be unambiguously guaranteed based on the findings in literature.

In the following, further research areas are pointed out. This work reveals a deep research deficit concerning DT startups in general. Based on the definition developed in this paper, German DT startups should be identified and surveyed in order to extensively validate the results in practice based on findings from the literature. The characteristics of the different investor types should be further examined not only in relation to the signals relevant for their investment decisions but also with respect to the role different investor types can take on in the investment process. In particular, the risk tolerance of the investors should be investigated in order to estimate which amounts of capital they could provide to a startup at a given stage of development. Furthermore, the considerations of the early development phase conducted in this work, should be expanded on the later stages of development. That could enable the development of long-term financing strategies for DT startups in which startups could reuse and advance the signals identified for the early phase as part of a strategic and systematic positioning on the market.

## Appendix

Table 1: Allocation of the signals to evaluation dimension

| Evaluation dimension | Subdimension | Signal |
|---|---|---|
| Team | Education | Years of education |
| | | Level of education [58]:<br>• Technical education [94]<br>• University degree [58,89,90]<br>• Dissertation [58,90]<br>• MBA [91,92]<br>• Professorship [89,95] |
| | | Reputation of university [93] |
| | Experience | Management experience [94,96]:<br>• Years in leadership position [89]<br>• Reputation of employer [97]<br>• International experience [98] |
| | | Startup experience [82]:<br>• Years as founder [82,87]<br>• Experience with investors [99]<br>• Experience with initial public offering [100]<br>• Parallel activity in other SUs [82] |
| | | Founding experience [82] |
| | Diversity | Founding in a team [81] |
| | | Team Size [58]:<br>• Board of Directors<br>• Top management team |
| | Motivation | Invested private assets [101] |
| | | Personal loans taken out [87] |
| | | Worktime in startup per week [87] |
| | | Capital from friends and family [102] |
| Technology | Degree of innovation | Originality of the patent [99] |
| | | Complexity of the logo [103] |
| | | Expenses for research and development [79] |
| | | Innovations without patents [104] |
| | | Negative comment by the patent office [94] |
| | Level of development | Progress in the patenting process [94] |
| | | Development stage of product [96] |
| | Defense | • Patent application [94]<br>• Granted patent [82] |
| | | Time after patent [99] |
| Sales market | Potential | Contradictions in the patenting process [94] |
| | | Sustainable customer group [105] |
| | Access | Contact to customers [106]:<br>• Prototypes tested with customers [81]<br>• Experiments with customers |
| | | Trademark registered [107] |
| | | Business plan [81] |
| | | Market orientation [108] |
| | | Alliances:<br>• Production partners [82]<br>• Marketing companies [82]<br>• Retail partners [82]<br>• Companies from the same industry [82] |

| Evaluation dimension | Subdimension | Signal |
|---|---|---|
| Sales market | Access | Uncertainty to reach market [94] |
| Resources | Network | Proximity to:<br>• Urban centers [96]<br>• Universities [96]<br>• Investors [93] |
| | | Participation in investor networks [96] |
| | | Personal network of founding team [92] |
| | | Regular communication [109] |
| | Capital structure | Won prizes [58] |
| | | Research grants |
| | | Received business shares |
| | | Desired Initial Public Offering (IPO) |
| | | Offered shares |
| | | Received capital during financing round |
| | | Existing equity investors [110]:<br>• PVCF investment<br>• Investor's Reputation<br>• Investor's level of education<br>• Investor's monitoring activities |
| | Infrastructure | Research alliances [111] |
| | | Permanent office [96] |
| | | Access to university technology [112] |

Table 2: Allocation of signals to evaluation dimension and investor types

| Evaluation dimension | Subdimension | Private Venture Capital | Business Angels | Crowd-Investors |
|---|---|---|---|---|
| Team | Education | Years of education | | Level of education<br>• Dissertation<br>• MBA |
| | | Level of education:<br>• Technical education<br>• University degree<br>• Dissertation<br>• Professorship | | |
| | | Reputation of university | | |
| | Experience | Management experience:<br>• Years in leadership position<br>• International experience | Management experience:<br>• Years in leadership position | |
| | | Start-up experience:<br>• Years as founder<br>• Experience with investors<br>• Experience with initial public offering<br>• Parallel activity in other SUs | Start-up experience | |
| | | Number of previous startups | | |
| | Diversity | Founding in a team | Founding in a team | Team size<br>• Board size |
| | | Team Size:<br>• Top management team | | |
| | Motivation | Director takes full responsibility | Capital from friends and family | Invested private assets |

| Evaluation dimension | Subdimension | Private Venture Capital | Business Angels | Crowd-Investors |
|---|---|---|---|---|
| Technology | Degree of innovation | Originality of the patent | | Complexity of the logo |
| | | Expenses for research and development | | |
| | | Innovations without patents | | Innovations without patent |
| | | Negative comment by the patent office | | |
| | Level of development | Progress in the patenting process | Prototype | |
| | | Prototype | | |
| | Defense | Patent:<br>• Patent application<br>• Granted patent | Patent | Patent |
| | | Time after patent | | |
| Sales market | Potential | Contradictions in the patenting process | | |
| | | Sustainable customer group | | |
| | Access | Contact to customers:<br>• Prototypes tested with customers | Contact to customers:<br>• Prototypes tested with customers | |
| | | Trademark registered | | |
| | | Business plan | Business plan | Business plan |
| | | Market orientation | | |
| | | Alliances:<br>• Production partners<br>• Marketing companies<br>• Retail partners<br>• Companies from the same industry | | |
| | | Uncertainty to reach market | | |
| Resources | Network | Proximity to:<br>• Urban centers<br>• Universities<br>• Investors | | Personal network of the founding team |
| | | Participation in investor networks | Participation in investor networks | Regular communication |
| | Capital structure | Research grants | | Investments by other crowd investors |
| | | | | Desired Initial Public Offering (IPO) |
| | | Existing equity investors:<br>• Investments by private venture capital funds<br>• Investor's Reputation<br>• Investor's level of education<br>• Investor's monitoring activities | | Investments by business angels or private venture capital funds |
| | | | | Length of the financing round |
| | | | | Offered shares |
| | | | | Won prizes |
| | Infrastructure | Research alliances | Permanent office | |
| | | Permanent office | | |
| | | Access to university technology | | |

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**Biography**

**Prof. Dr.-Ing. Dipl.-Wirt. Ing. Günther Schuh** (*1958) holds the chair for Production Engineering at RWTH Aachen University. Furthermore, he is director of the FIR e. V., member of the board of directors of the WZL of the RWTH Aachen University and the Fraunhofer Institute for Production Technology (IPT).

**Carolin Hamm** (*1991) holds a M.Sc. degree in Business Administration and Engineering (Mechanical Engineering) from the RWTH Aachen University. Since 2019, she is a research fellow (Dr.-Ing-) in the department Strategic Technology Management at the Fraunhofer Institute for Production Technology (IPT).