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Proposal of a Holistic Maturity Model for Technology, Market and Founders

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Abstract

Academic spin-offs are a particularly efficient form of exploiting scientific knowledge. The premises for a promising spin-off are that the technology is soundly founded and the market strategy is carefully considered and solidly planned. Also, the founder profile should prove personal, professional and entrepreneurial aptitudes. Maturity models (MM) can serve as guidelines that support founders in overcoming the discrepancy between the actual and target state in the spin-off process. However, none of the existing MM that has been identified, covers all these three aspects: technology, market and founder. The MM described in this paper should close this gap. The developed MM comprises nine levels and is described by three dimensions: technology, market and founder. The MM is structurally built on two models, Technology Readiness Levels and Market Readiness Levels. The dimension "Founder" is divided into four sub-dimensions (personality & motivation, skills & network competencies, team structure & culture and image & support from the university) for which proven success factors were used. The MM was checked for completeness and sequence logic and adapted. Finally, an assessment tool was developed, which was then tested and evaluated - together with the MM - by selected experts. The validation demonstrated a high level of

applicability and practical relevance. However, limitations of the MM also became apparent during the evaluation, which offer starting points for further development of the model and the assessment tool. Also, the MM must be empirically checked based on the quality criteria that have been worked out (relevance, objectivity, etc.).

Keywords: academic spin-offs, start-ups, maturity model, entrepreneurship, market readiness

1. Introduction

1.1 Relevance of the Topic

In a highly developed economy, knowledge is the most important production factor and contributes significantly to the competitiveness of a country. Universities play a key role here - through their contributions to basic and applied research, as well as in experimental development. Scientific findings lead to start-ups that develop products/services based on them and thus improve quality of life and contribute to economic growth. The universities' ongoing IPR (intellectual property rights) and exploitation strategies include goals and measures for a broad spectrum of exploitation (patents, licenses, spin-offs, etc.) and hence make a substantial contribution to professional, strategic knowledge and technology transfer. Academic spin-offs (ASO) in particular play an essential role when it comes to turning a good technological idea into an innovation. (BMBWF, 2021b), (Shane, 2002), (Stam, Suddle, Hessels, & van Stel, 2009), (Audretsch, 2009)

The current national strategy for research, technology and innovation mirrors this, the increasing of the number of economically successful academic spin-offs was included as a goal in the Austrian government program and anchored accordingly (Federal Government of Austria, 2020b).

1.2 Problem

Knowledge and technology transfer to the economy is of the highest relevance for a country's science, economy and society. To increase output, academic knowledge must therefore be exploited in a more targeted manner. A particularly efficient form of knowledge exploitation is founding ASO (Festel, 2013). They develop - often in cooperation with their university/research institute – new technologies, products, processes, or business ideas, create jobs and therefore are very important for the regional business (BMBWF, 2021b). So far, the number of ASO in Austria has shown a relatively low upward trend (BMBWF, 2021b), which may also be due to careful examination by the university of origin (Ecker & Gassler, 2016). Despite their small number, ASO are of great importance in research, politics and business, since they exploit a large part of innovations commercially and their radical technological innovations can develop strong economic effects (Shane, 2004; Dickel, 2009).

However, studies suggest that ASO use radical technologies at a very early stage of development. Thus, at the time of the spin-off, it is often unclear which customers will benefit most from the technology and in which form (product/service) potential customers would be interested in it. Especially in the pre-seed phase, ASO often lack the market knowledge, business contacts and industry experience to assess market needs or develop a

promising prototype. Also, in the market entry phase, ASO often lack business knowledge, patenting experience, access to resources and legitimacy to attract business partners. In the growth phase, it is particularly management skills and a good understanding of market conditions that are available to an insufficient extent in ASO. These deficits are thus potential causes for the fact that many ASO do not succeed in establishing themselves successfully and permanently on the market. (Spath & Walter, 2012; Riesenhuber, Walter, & Auer, 2009)

A MM that assesses the development status of the start-up - in terms of technology, market and founder/founding team - can serve as a guideline and thus offer the ASO support in overcoming the discrepancy between the current and target status in the spin-off process. By systematically determining the development level, statements can be made, e.g. whether a technology/service is ready for use/launch. In addition, by checking personal, professional and entrepreneurial suitability (founder/founding team dimension), the founders have the opportunity to identify their own weaknesses and to remedy or compensate for them in a targeted manner.

1.3 Objectives and Research Questions

Based on the aforementioned problem, the core objective of this work was to develop a MM that allows the assessment of ASO - with a focus on technology, market and founder/founding team.

The following research objectives were formulated:

- Gain knowledge of existing MM for technology, market and founders as well as identify their strengths/weaknesses, application examples and approaches for (further) development;
- Development through combination, further development or new conception of a practice-oriented holistic MM for ASO, with a focus on technology, market and founder/founding team.

1.3 Methodology

- Literature research and evaluation: identification and comparison of existing MM for technology, market and founders to create the basis for the development of the holistic MM;
- Identification of potential development models for MM as well as the development of the MM according to a proven method;
- Evaluation of the resulting MM through self-application and personal interviews with selected experts.

2. Theoretical Framework

2.1 Importance of Academic Spin-Offs

ASO are generally defined as spin-offs from universities or public research institutions (PRI) to exploit scientific findings or acquired competencies (Bagdassarov, 2012). In this paper, ASO are defined according to the following three characteristics (Schleinkofer, 2013):

- Personal proximity: the founders are connected to the university/PRI as professors, researcher, students or alumni;
- Factual proximity: knowledge or research findings form the basis of a business idea;
- Temporal proximity: the founding process is timely close to what is being researched/learned at the university/PRI.

In our definition, the spin-off process begins with the first actions of the nascent entrepreneurs.

The targeted valorisation of academic knowledge and inventions has increasingly become the focus of attention in science and innovation policy in recent years, which has also forced the responsibility of universities not only as knowledge carriers but also as knowledge providers in the economy and society. (Ecker, Gogola, & Danler, 2021; BMBWF, 2021c; Jud & Kleinberger-Pierer, 2018)

The organisation of knowledge has a central role in all business theories as well as in the development and founding of companies. Knowledge itself is seen as an important competitive factor and its transfer as a critical factor for increasing productivity and innovative capacity. From an economic point of view, not least to strengthen economic development and growth, technology-based companies in particular play a key role. The emergence of new disciplines and the dynamics in technological fields, as well as the increasingly necessary multidisciplinarity, also contribute to the growing importance of a broader and more diverse research environment. ASO can make a special contribution to this. (Ecker & Gassler, 2016).

In Austria, too, increasing attention is being paid to the importance of ASO for dynamic economic development. Thus, several concrete goals and measures have been defined in various areas of the national research and innovation system (Federal Government of Austria, 2020b). One of them is to “push spin-offs” (Federal Government of Austria, 2020a) with the ambitious goal of increasing the number of ASO in knowledge and technology transfer by 100%. (BMBWF, 2021a). The hope is not only to strengthen the transfer of knowledge and technology from the universities to the economy and society but above all to support economic growth, especially the creation of jobs (Ecker & Gassler, 2016).

2.2 Success Factors: Technology – Market – Founder

The literature review for this work revealed that ASOs license technologies at an earlier stage of development, with less reference to established technological knowledge and with a broader range of industrial applications than established companies. However, the development of young technologies and the marketing of technology-based products/services are associated with a high degree of uncertainty. In the case of a technology transfer from public research, it is often initially unclear who benefits most from the technology and in what form potential customers would be interested in the technology. In addition, the commercial success of the ASO is hampered by a lack of industry and management experience and a lack of market orientation on the part of the founders due to their scientific

background. As a result, many ASO do not succeed in establishing themselves permanently on the market. (Riesenhuber, Walter, & Auer, 2009)

The founder constitutes – in this context – another critical success factor, according to scientific literature. His personality is given the greatest relevance, even ahead of his professional and business qualifications.

In summary, for successful entrepreneurial activity, it is crucial that the founder/founder team optimally perceive the possibilities of exploiting research results, master the technology and at the same time realistically assess the market conditions.

Against this background, for the development of the MM, the success factors that have been recognized in previous research were first brought together and assigned to the three perspectives - technology, market and founder (Table 1).

Table 1. Success factors

Dimension	Success factors	References
TECHNOLOGY	strong technology base	(Dickel, 2009; Schmidt, Heinrichs, & Walter, 2011)
	high level of innovation patentability	(Poponi, Braccini, & Ruggieri, 2017; Nerkara & Shaneb, 2003; Preston, 2001; Hasenauer, 2014; Hemer, Berteit, Walter, & Göthner, 2006)
	clear technology differentiation	(Shane, 2004; Hemer, Berteit, Walter, & Göthner,
	product orientation	(Roberts, 1991)
	wide range of applications	(Shane, 2004)
	high growth industry	(Helm & Mauroner, 2007)
	good availability of qualified employees	(Helm & Mauroner, 2007)
MARKET	market research and analysis	(Hemer, Berteit, Walter, & Göthner, 2006; Dickel, 2009; Helm, Mauroner, Dowling, & Pöhlmann, 2013; Cleyn, Jacoby, & Braet, 2009; Zahradnik, Leitner, Raunig, Dömötör, & Jung, 2020)
	advanced product marketing and sales strategy definition	(Hemer, Berteit, Walter, & Göthner, 2006; Cleyn, Jacoby, & Braet, 2009)
FOUNDER	*personality and motivation*: achievement motive, self-reliance, leadership, tolerance of ambiguity, creativity/curiosity, internal control conviction, assertiveness, passion, learning orientation, personal commitment, willingness to take risks, etc.	(Bigliardi, Galati, & Verbano, 2013; Fallgatter, 2002; Oberländer, 2017; Cromie, 2000; Jacobsen, 2006; Shane, 2004); (Hemer, Berteit, Walter, & Göthner, 2006; Bernhard, 2009; Poponi, Braccini, & Ruggieri, 2017; Geißler, 2013; Niemand, Hoffmann, & Ott, 2009)

	capabilities and networking skills: business knowledge, technological know-how, commercial knowledge, knowledge of business best practices. social skills, start-up preparation, high education level, industry/practical experience, etc.	(Hemer, Berteit, Walter, & Göthner, 2006; Vihervuori, 2017; Hossinger, Chen, & Werner, 2019; Nielsen, 2014; Dowling, 2003); (Schmidt, Heinrichs, & Walter, 2011; Unger, Rauch, Frese, & Rosenbusch, 2011; Davidsson & Honig, 2003)
	team structure and culture: founding teams (instead of a single founder), flat hierarchy, clearly defined roles within the team, heterogeneous set-up (e.g. researchers and non-researchers), good chemistry, good/healthy team culture, etc.	(Hemer, Berteit, Walter, & Göthner, 2006; Egeln, Gottschalk, Rammer, & Spielkamp, 2002; Ben-Hafaïedh & Cooney, 2017; Bigliardi, Galati, & Verbano, 2013; Bernhard, 2009); (Schmidt, Heinrichs, & Walter, 2011; Vihervuori, 2017; Ecker & Gassler, 2016; Schleinkofer, 2013; Poponi, Braccini, & Ruggieri, 2017); (Hossinger, Chen, & Werner, 2019)
FOUDNER (cont.)	*image and support from parent organisation:* expertise (consulting, coaching), access to networks or industry partners, contact intermediation, material support (rooms, equipment, staff, etc.)	(Schleinkofer, 2013; Bigliardi, Galati, & Verbano, 2013; Hemer, Berteit, Walter, & Göthner, 2006; Poponi, Braccini, & Ruggieri, 2017; Hossinger, Chen, & Werner, 2019); (Sandkuhle, 2017; Ecker & Gassler, 2016)

2.3 Maturity Models

Maturity models (MM) assume that predictable patterns exist in the development of organisations, which are described as evolutionary stages or maturity levels. These distinct, individual stages provide a kind of roadmap for change in organisations. The practical use of maturity models is to determine the current situation of an organisation in a structured way, to derive and/or prioritise improvement measures based on this, and to subsequently monitor the success of their implementation. (Becker, Knackstedt, & Pöppelbuß, 2010; de Bruin, Freeze, Kulkarni, & Rosemann, 2005)

In the scientific literature, two types of MM are distinguished:

- Optimisation models (maturity/capability models) - show an idealised path of improvement for a particular subject area.
- Assessment models - evaluate certain characteristics of an object area. (Mettler, 2010a)

Following (de Bruin, Freeze, Kulkarni, & Rosemann, 2005) and (Hecht, 2014) MM are characterised, according to the understanding of this paper, by the following elements in particular:

- MM comprise a number of *development stages* for the considered *dimension*, referred to as *maturity levels*.

- Each stage of the development comprises a certain set of *requirements* that must be met to reach that level of maturity.

The determination of maturity level can be carried out using various assessment procedures: self-assessment (e.g., employing a questionnaire) and/or external assessment, i.e., assessment by independent consultants, assessors or certification bodies. (Becker, Knackstedt, & Pöppelbuß, 2009; de Bruin, Freeze, Kulkarni, & Rosemann, 2005)

4. Development and Evaluation of Maturity Models

4.1 Methodical Approach

The development approach in this work is based on the development model for MM according to (Becker, Knackstedt, & Pöppelbuß, 2009). Compared to other methods, this offers the greatest level of detail in the description of the individual phases (Hecht, 2014). In deviation from the original model, the last three development steps - *conception of transfer, implementation* and *evaluation* - are combined into one overarching phase – *evaluation*, in order to achieve a similar scope for each development phase (Figure 1).

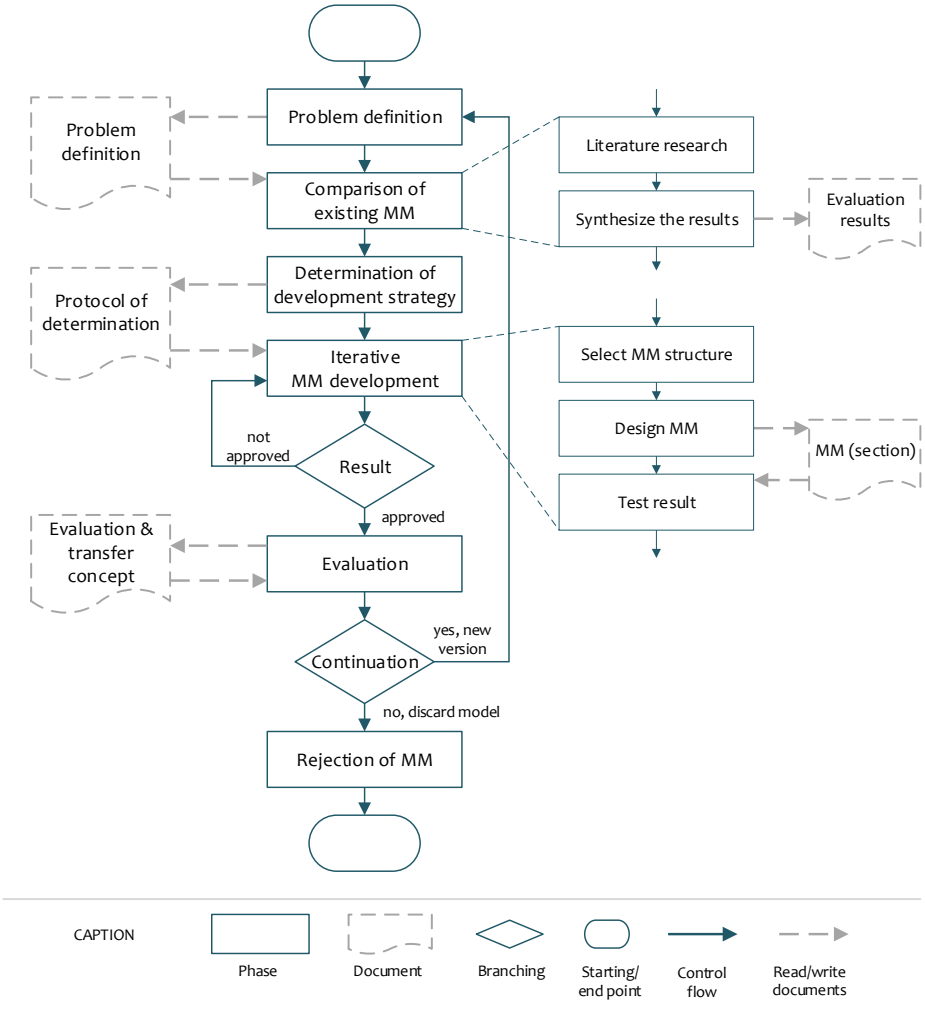

Figure 1. MM development approach, based on (Becker, Knackstedt, & Pöppelbuß, 2009)

4.1.1 Problem Definition

The first step is to define the addressed area (organisation, department, sub-discipline, etc.), the target group, and the objective of the MM (e.g., a comparison of different organisations or the identification of improvement potential) (Becker, Knackstedt, & Pöppelbuß, 2009; Maier, Moultrie, & Clarkson, 2012; Hecht, 2014). In addition, detailed requirements for the MM are also formulated in this stage, these will guide later the development and evaluation of the model (Hecht, 2014).

The problem definition and relevance of the holistic MM were already pointed out in **0.**

1. Introduction.

The requirements for the MM were derived from the problem definition and listed in

Table 2.

Table 2. Requirements for the holistic MM

Req. Type	Requirements
Application	The MM … - should be an assessment model - can provide support in determining the timing of the spin-off - should enable the user to derive improvement potentials or next steps - can be used regardless of sector, but is primarily aimed at technology-oriented start-ups - support both self-assessment and external assessment
Architecture	The MM … - should consist - if possible - of existing, tried and tested MM - should cover the areas: technology, market and founder(s) The overall maturity should result from the combination of the maturity of the individual dimensions: technology, market and founder(s).

Based on the findings of existing and generalisable quality characteristics of MM a proposal for quality criteria for the holistic MM was defined (shown in

Table 3).

Table 3. Quality criteria of MM development, based on (Rammstedt, 2010) and (Khan, 2016)

Criteria	Description
Objectivity	The MM should arrive at comparable results when investigating the same problem and using the same methods, regardless of the person conducting the investigation. There are clear instructions on how to conduct the interview and only closed response formats are used, then the objectivity of the MM can be considered assured (Rammstedt, 2010).
Reliability	The MM should deliver reproducible results, i.e. the maturity level should be determinable without being influenced by situational or random circumstances. Subsequently, the MM should contain indicators that can be identified and determined beyond subjective perception (Rammstedt, 2010; Khan, 2016).
Validity	The MM should measure what it is supposed to. The survey should therefore consider as many aspects of the dimension being measured as possible (Rammstedt, 2010).
Relevance	The MM should contain all those indicators without whose existence the benefits of MM use would decrease, i.e., it should only consider aspects that are relevant for determining the maturity level (Khan, 2016).
Applicability	The theoretical and empirical knowledge embodied in the MM should be transferable to the target object (Khan, 2016).
Manageability	The MM should enable efficient use (Khan, 2016).

4.1.2 Comparison of Existing Maturity Models

In the second development phase, the necessity of the MM to be developed is justified. The MM can also just be an improvement of an existing model. Often, weaknesses of a known MM or lack of transferability to another application area are taken as a reason for further development (Becker, Knackstedt, & Pöppelbuß, 2009).

The literature research undertaken for this work revealed several different MM; (de Bruin, Freeze, Kulkarni, & Rosemann, 2005) put the number in 2005 at over 150 MM. The MM relevant to the topic were selected on the basis of four criteria, presented in .

Table 4.

Table 4. Classification criteria for the selection of MM, according to (Mettler, 2011)

Criterion	**Characteristics**		
Focus	MM in the context of ASO, start-up, or entrepreneurship	MM for the evaluation of technology	MM for assessing market maturity
Application	self-assessment assessment model	accompanied assessment (e.g. by independent experts)	assessment by external experts or certified assessors
Maturity concept	person/team oriented		object-oriented (technology and/or market)
Origin	scientific publication		practice (consultancies, independent experts, certification bodies, etc.)

Table 5 shows the most relevant models that were identified by the literature review. All these

MM are derived from scientific research. It is striking that all identified models for assessing technology maturity were derived and adapted from the original TRL model - developed for the National Aeronautics and Space Administration (NASA). The literature research also showed that most models focus primarily on the technology or technical aspects, while the market potential/analysis and the associated risks receive little attention. The models identified provide no or only insufficient information about the market maturity of a technology.

No known or scientifically recognised MM could be identified for determining the maturity level of founders.

Table 5. Relevant MM

MM	Description
Technology Readiness Levels (TRL)	the first approach to determining technology maturity; originally developed for the National Aeronautics and Space Administration (NASA) and later adopted by the European Space Agency (ESA) (TEC-SHS, 2008; Mankins, 1995; Mankins, 2009)
Demand Readiness Level (DRL)	was developed to better monitor innovations in terms of market potential (Paun, 2011a; Paun, 2011b)
Solution Readiness Levels (SRL)	was developed for transdisciplinary projects to determine their progress (Schön, Eismann, Ansmann, & Wendt-Schwarzburg, 2016)
Balanced Readiness Level Assessment (BRLa)	An approach for assessing new agricultural technologies; based on the TRL model and extended by four additional dimensions: Market Readiness Level, Regulatory Readiness Level, Acceptance Readiness Level and Organizational Readiness Level (Vik, Melås, Stræte, & Søraa, 2021)

Market Readiness Level (MRL)	was developed as part of the *European Corridor - Austrian Testbed for Cooperative Systems* project to provide stakeholders with guidance on the use of *Cooperative Intelligent Transport Systems*; establishes a correlation between TRL and DRL (Hasenauer, 2014; Hasenauer, Weber, Filo, & Orgonáš, 2015; Schildorfer, Aigner, & Hasenauer, 2017)

4.1.3 Determination of Development Strategy and Basic Structure

A comprehensive comparison is a prerequisite for a well-founded determination of the development strategy. Depending on the availability of suitable models, the following essential basic strategies can be distinguished: completely new development, further development of a single MM, a combination of several models to form a holistic MM, as well as the transfer of structures or contents of existing MM to new areas of application (Becker, Knackstedt, & Pöppelbuß, 2009).

The basic structure of the proposed MM (Table 6) was created by combining the models TRL – version used by ESA (TEC-SHS, 2008) and MRL (Hasenauer, Weber, Filo, & Orgonáš, 2015). These evolved MM was later adapted and complemented. The dimension *Founder* required a new development; its sub-dimensions were thus derived from the success factors identified. The structure of this dimension is based on the classification model of success factors for spin-off founders by (Helm & Mauroner, 2007).

Table 6. Basic structure of the MM (source: own elaboration)

Dimensions	**Sub-dimensions**	**Remarks**
Technology	-	Maturity levels of the technology
Market	-	Aspects considered: - Demand for product/technology - Customers and their needs for the proposed technology/service - The competitive situation, market feasibility of the business idea, marketing, environment, sector, etc.
Founder	Personality and Motivation (P&M)	Personality traits and motives that favour entrepreneurial action (proactive behaviour): need for achievement, perseverance, willingness to take calculated risks, entrepreneurial vigilance, the conviction of internal control, need for independence, self-fulfilment, tolerance of ambiguity, etc.

Capabilities and networking skills (C&N)	Knowledge and natural or acquired abilities of individuals, who are thus in possession of performance potential, social competence, network competence, relationship portfolio, etc
Team structure and culture (T&C)	Characteristics of the founding team: hierarchy, culture, set-up, etc.
Image and support by parent organisation (I&S)	Characteristics of support from the parent organisation and its image: quality of the relationship (poor, non-existent), intensity (e.g. too close a relationship has a negative impact on the development of spin-offs), etc.

4.1.4 Iterative Maturity Model Development

The central phase of the design process is the iterative model development. The sub-steps of defining the design domain, selecting the procedure, designing the model domain and checking the result are repeated several times (Becker, Knackstedt, & Pöppelbuß, 2009).

During this development phase, various design decisions have been made: the understanding of maturity used, the specific procedure in model development (combination and creation), the form of presentation of the model (assessment tool), etc. (Mettler, 2010b; Hecht, 2014). The sub-steps Select MM structure, Design MM and Test result (Figure 1) were repeated several times and ultimately formed the structure of the holistic MM. At the end of each iteration, the MM have been checked in particular for completeness, consistency and problem adequacy.

Technology dimension: The refined TRL version from ESA – which is also used by European technology funding programs (Héder, 2017) was rated as the most suitable. ESA's TRL has got detailed, freely accessible documentation and defines a standardised procedure consisting of four steps that must be carried out for each technology maturity level; for full details see (TEC-SHS, 2008). The review of the TRL model and the accompanying documentation showed that these could be adopted without any relevant adjustments. The high level of awareness and the wide use of the model also confirmed this decision.

Market dimension: The analysis of the content showed that the MRL model identified was insufficiently detailed in terms of requirements and lacked a flow logic for the steps a spin-off needs on its way to market maturity. In addition, the analysis of the industry/market structure, as well as other prerequisites for a promising market entry (market feasibility of the business idea, environment analysis, market analysis, marketing strategy, saleability of the product/service offering, development of a marketing channel, etc.), were insufficiently covered by requirements. Consequently, the original MRL has been analysed through Porters Five Forces Model and supplemented accordingly. Finally, all maturity levels and their

requirements were reviewed in terms of their level of detail and sequence and adapted or expanded again.

Founder dimension: The sequence of maturity levels here does not describe an anticipated or desired development path. Instead, this dimension was designed as an aptitude test to check the extent to which the founders of an ASO are suitable as entrepreneurs. The maturity levels were defined as a percentage, corresponding to the achieved share of the ideal maturity profile (maximum score). The overall maturity score is calculated from the differently weighted individual scores of the four sub-dimensions, *P&M*, *C&N*, *T&C*, and *I&S* (Table 7).

P&M contains several personality traits about which there is an agreement in the scientific literature that they are directly action-shaping characteristics of entrepreneurs: achievement motivation, the conviction of control, creativity, learning orientation, etc. (Fallgatter, 2002; Korunka, Frank, & Lueger, 2004; Meyer, 2020); these characteristics were subsequently used as indicators for the sub-dimension personality and motivation.

C&N comprises knowledge and skills that are considered in the scientific literature to be essential for the entrepreneurial aptitude of founders: business knowledge, task-specific skills (e.g. technology, design), network competence, professional/industry experience, management experience, etc. (Moog, 2004; Schwarz, Almer-Jarz, & Harms, 2007; Huynh, 2016). The network competence and the relationship portfolio of the founders are of particular importance in this context, as cooperation makes it possible to use one's own resources more efficiently and to draw on external resources that are critical to success (Gese & Klandt, 2003; Poponi, Braccini, & Ruggieri, 2017; Riesenhuber, 2008).

T&C refers to the nature of the founding team as well as the lived team culture. In the literature, the size of the founding team is often seen as an indicator of the success potential of a young company, but there are no reliable empirical findings on the optimal size of the founding team, which may also vary greatly from sector to sector. (Egeln, Gottschalk, Rammer, & Spielkamp, 2002; Lechler & Gemünden, 2003). The advantages of team start-ups over individual start-ups are often derived from the combination of characteristics (age, education, background, professional experience, personalities, etc.) of individual founders (Lechler & Gemünden, 2003). Through a heterogeneous team set-up, there is the possibility to complement individual skills of the individual and compensate for potential know-how deficits but also to increase the creative potential (Schultz, Mietzner, & Wagner, 2012). Teams with heterogeneous industry experience have more potential for success in the long term. (Hossinger, Chen, & Werner, 2019; Poponi, Braccini, & Ruggieri, 2017). This is sometimes justified by the fact that tensions arising from the different backgrounds of experience are translated into new ideas and approaches. Also, negative effects such as "operational blindness" or "inexperience" are compensated for by team heterogeneity (Lechler & Gemünden, 2003).

Another significant factor influencing cooperation and thus team performance is the team culture: it determines the nature of cooperation and forms the basis of teamwork for which those involved are highly motivated and willing to perform. A team culture based on respect,

trust and partnership is therefore indispensable. (Hemer, Berteit, Walter, & Göthner, 2006; Bernhard, 2009; Schmidt, Heinrichs, & Walter, 2011)

I&S includes success indicators related to the spin-off's relationship with the parent organisation (PO). An obstacle to the positive development of a spin-off can be, e.g., a poor, unregulated or too close relationship with the PO (Semadeni & Canella, 2011). A lack of communication or trust with the PO, or different objectives can also harm the development of the spin-off, especially in the early phases.

The overall maturity in the dimension *Founder* results from the sum of the individual values of its four sub-dimensions. However, since a variety of combinations of the maturity of the individual sub-dimensions can lead to the same overall maturity of the dimension, no definitions for individual maturity levels and no concrete requirements were defined. Nevertheless, to show a development path and facilitate assessment, four maturity levels were defined, as shown in

Table 7. The determination of the weighting of the individual sub-dimensions in the dimension *Founder* was done by pairwise comparison. The sub-dimension *P&M* was rated as the most important and *I&S* as the least important. Reason: *P&M* contains traits that are stable across time and situation (e.g., motivation, internal control conviction, tolerance of uncertainty, etc.) and, consequently have a stronger influence on entrepreneurship. As the second most important subdimension, the *C&N* was determined; it includes changeable traits that are developed through education, experience, practice or training and, as professional, social and methodological competencies, can foster entrepreneurial ambitions (Müller, 2010; Koetz, 2006; Gerig, 1998).

Table 7. Basic structure of the holistic MM

(ML=maturity level, AP=achieved percentage of maximum score in the dimension *Founder*)

ML	Technology	Market	AP	Founder(s)
1	Basic principles observed and reported	Unmet need in the market identified	up to 20%	Lack of entrepreneurial suitability
2	Technology concept and/or application formulated	Potential business opportunity identified	21%-30%	
3	Analytical and experimental critical function and/or characteristic proof-of-concept	Environment and framework conditions analysed	31%-40%	Average entrepreneurial aptitude
4	Component and/or breadboard validation in a laboratory or simulated environment	Market and customer analysed	41%-50%	
5	Component and/or breadboard validation in a relevant environment	Competitive and industry structure analysed	51%-60%	
6	System/subsystem model or prototype demonstration in a relevant environment	Corporate and marketing goals defined	61%-70%	Good entrepreneurial aptitude
7	System prototype demonstration in an operational environment	Positioning strategy defined	71%-80%	
8	The system/technology is fully developed and qualified	Value propositions defined	81%-90%	High entrepreneurial aptitude
9	System/technology proven in an operational environment	Product/service and business model coherently described	from 91%	

The TRL model with its levels is widely used and very well known. In the case of the founder's maturity level, no continuous development path is possible due to the composition of four dimensions. For this reason, only the market maturity levels are described here.

Table 8. Detailed requirements of the market dimension

ML	Requirements for achieving the maturity level
1	1.1 The hypothesis of possible market demand was made. 1.2 A gap in the market or a potential for improvement (product/technology/service) has been discovered. 1.3 With the help of the new product/technology/service, it is possible - to solve a problem or to satisfy a need, - to save costs/time, - to achieve any other benefit. 1.4 Target market and group have been identified.
2	2.1 The new business idea may be able to awaken or satisfy a need so that the customer is willing to pay for it appropriately. 2.2 The market feasibility of the business idea - i.e., the nature of a target market and whether market entry can be reasonably accomplished - has been examined. 2.3 The needs of the lead users have been identified. 2.4 Similar competing or substitute product/technology/services have been identified.
3	3.1 The expected functionality of the new product/technology/service has been identified and described. 3.2 All relevant stakeholders for the implementation of the founding have been identified. 3.3 An analysis of the environment (property right situation, market size, industry development, legal framework, etc.) was carried out. 3.4 A performance options plan and an extended performance family have been developed.
4	4.1 The expected functionality of the new product/technology/service has been quantified. 4.2 Needs and problems of customers were collected and confirmed through information gathering (sufficient interviews/surveys, on-site analyses, experiments, or tests). 4.3 A market analysis, i.e., a systematic evaluation of the information regarding market volume, market potential, market growth, market segments, buying behaviour, etc. was carried out. 4.4 Trust was built with selected target customers.
5	5.1 The system capability of the new product/technology/service has been identified and described. 5.2 A competitive analysis was carried out, i.e., information on existing/potential competition, competitive intensity, barriers to market entry, substitute products, etc. was determined and analysed. 5.3 The bargaining power of customers was analysed, i.e., information on customer groups, purchase quantities, degree of standardisation of products, distribution capacities, dependence on certain distribution channels, the loyalty of customers to certain brands, etc. was determined and analysed. 5.4 The bargaining power of the suppliers was analysed, i.e., information on availability of the required materials/goods, exchange costs, etc. were determined and analysed.
6	6.1 The expected functionality of the new product/technology/service has been translated into the required capabilities. 6.2 Selected customers have already confirmed the benefits of the new product/technology/service. 6.3 The marketing strategy has been defined and business and marketing objectives have been derived. 6.4 A marketing plan has been developed.

7	7.1 Key resources and the necessary & sufficient competencies for market entry have been defined. 7.2 Extended test sales (pre-series/zero series) have taken place. 7.3 A positioning statement was formulated. 7.4 Required certification or regulatory approval has been obtained.
8	8.1 Professionals (experts) with the defined competencies (7.1) were identified. 8.2 Initial sales/services have already been made. 8.3 Active service and support were provided to the customers. 8.4 Value/benefit proposition has been defined.
9	9.1 Market demand/scope of services has been fully developed. 9.2 The new product/technology/service or technology application has been conclusively defined. 9.3 The saleability of the product/technology/service has been ensured (i.e., sales staff training, and product documentation). 9.4 A marketing track has been established and the product/technology/service has been sufficiently promoted.

The MM was implemented as a checklist: relevant requirements were formulated as closed questions and compiled into a questionnaire (technology and market: 36 questions each, founder: 89 questions divided into the four sub-dimensions).

4.2 Evaluation of the Model

The evaluation of the holistic MM was carried out using guideline-based interviews with four start-ups from different sectors (software/IT services, agricultural technology/agriculture and medical technology) that are now successful on the market. One member of the founding team was always interviewed.

The demonstration of the application of the assessment tool and the interviews provided relatively good evidence of the relevance, usefulness and practicality of the MM. All relevant aspects related to technology, market and founder(s) were considered to be sufficiently covered. A self-assessment can also be carried out with reasonable effort, but the results should be interpreted with caution, as this method may be characterized by a high degree of subjectivity.

The MM is well suited as a guide in the foundation/spin-off process and, thanks to its standardized questionnaire, also offers a practical opportunity to evaluate and compare the degree of maturity of different start-ups/spin-offs or to record their development steps. The MM was also reviewed concerning the quality criteria developed.

The MM examines the same problem (development stage of an ASO) and - due to the given form of the survey (standardised questionnaire) - achieves similar results for each assessment, regardless of the user. Thus, the *objectivity* of the model can be considered reasonably assured. For more objectivity, however, it is recommended that external experts accompany the evaluation.

The *reliability* of MM could also be proven: the development was carried out according to proven methods, components of the MM are models whose reliability has already been proven, and the MM was tested by experts and assessed as reliable. However, there is still a need for further research to demonstrably prove the reliability of the model.

The *validity* (the model should measure what it is supposed to) is strongly dependent on the truth content of the answers given: although standardised questionnaires are used that cover all aspects of a dimension, the conduct of the survey is always subject to fluctuations. Thus, the results - especially in *Founder* - can be subjective on the one hand, as they represent the views and statements of individuals, and on the other hand, they are based on actual experiences and situations experienced.

The *relevance* of MM (model should only consider aspects that are relevant for determining the maturity level) was ensured by basing the development on sound scientific approaches and testing the model by experts.

Applicability and *manageability* were evidenced by the four experts interviewed during the evaluation.

5. Limitations

The developed MM is only as good as its components.

Critics of the TRL point out that the concept is subjective, imprecise and poorly defined, so decisions made based on a TRL assessment have limited validity. The TRL provides a general description of a particular technology and thus allows comparison of technologies, but is limited in terms of accuracy and precision. (Cornford & Sarsfield, 2004).

Possibly the most relevant disadvantage of the MRL component is the lack of scientific studies that could prove the benefits and validity of the model. Furthermore, the MRL - despite adjustments and extensions made in the course of this work – is probably still insufficiently defined and documented. Expert interviews have shown that a higher level of detail in the formulation of the requirements would limit the scope for subjective interpretations and thus lead to results that are closer to reality. However, this could be at the expense of manageability or practicality due to the higher effort involved.

The dimension *Founder* was designed as an aptitude test for ASO and evaluated based on expert interviews, but no empirical studies have yet been conducted to confirm its validity. The fact that only founders were interviewed means that the perspective of non-founders or founding teams that have failed is also missing.\

6. Outlook

The evaluation of the MM with the experts demonstrated high applicability and practical relevance. However, the demonstration and evaluation also revealed limitations of the MM that offer starting points for further development of the model and the assessment tool.

Thus, during the evaluation, indications were collected on the optimisation possibilities that can be considered in the further development of the MM (e.g., description of the

requirements, design of the assessment tool, web implementation of the assessment tool, etc.).

The starting point for further research is the empirical verification of the MM based on the presented quality criteria. An in-depth look at the processes, tasks and problems regarding market entry that ASO are confronted with in the start-up/spin-off process represents another opportunity for future research.

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