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RESEARCH ARTICLE

Model Proposal for Evaluation of Technology Development Process: Conceptualisation and Scale Development*

Fethi Aslan[1]

Abstract

Traditional approaches based on intuitive decisions of executivies, teams, or individuals often prove inadequate in managing complex technology development processes. Theoretical models proposed for successful technology development processes emphasize the necessity of standardized processes. However, empirical evidence regarding the applications and results of these models is limited. In this context, a model has been developed to examine how standardized technology development processes are implemented at the organizational level in companies. This model is defined by a scale that includes dimensions of technical research, business research, development, and performance. The proposed model is based on data obtained from companies with the highest R&D expenditure in Turkey. The findings provide evidence that a structured technology development process at the corporate level is necessary for success. It has been revealed that technical and business research phases are particularly determining factors in the development process. Additionally, it has been determined that the correct implementation of these processes has a positive impact on the performance of the process.

Keywords: Technology development, Standardised process, Exploratory factor analysis, Confirmatory factor analysis, Scale development

Introduction

As a result of globalisation, national businesses increasingly face competition from foreign businesses in distant regions of the world (Griner, Keegan, & Goldin, 2000, p. 19). Businesses are under pressure from the increasing complexity of customer demands and rapid changes in user experience, quality, performance and consumer attitudes. In addition, the intensity of competition and the pace of technological development are increasing businesses' challenges (Iansiti, 1995, p. 259).

New technologies can be applied to existing or new products, services and processes. These new technologies may change the conditions of competition and contribute to the

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1 **Corresponding Author:** Fethi Aslan (Dr.), Elazığ Special Provincial Administration, Elazığ, Turkiye.. E-mail: fethi.aslan@outlook.com ORCID: 0000-0002-5567-9706

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emergence of new markets (UNFCCC, 2017, s. 6). Businesses have been looking for new solutions for a long time to gain competitive edge and adapt to changing conditions. Developing appropriate technologies to meet current needs and future trends is recognised as a key solution. Related to this solution, it is also necessary to shorten the technology development time and increase the success rate (Griner et al., 2000, p. 29). In this way, businesses can maintain their competitive advantage and increase their growth potential.

The technology development process encompasses all decisions, actions, and capabilities involved in defining activities from idea exploration (opportunities) to transitioning to production. Its goal is to develop new items, components, systems, products, methods, or to enhance existing products and processes. This involves preparing the correct information at the appropriate level of detail and systematically implementing. As stated in the definition, technology development is a complex process involving many activities. It requires long-term effort and is characterised by high uncertainty. This is why careful planning and a flexible management approach are so important. Uncovering the unknown is the source of uncertainty. Uncertainty and complexity increase enterprises' risk levels in the technology development process. A high risk level leads to the failure of technology development activities (UNFCCC, 2017, p. 6). One of the main reasons for these risks is that technology development activities are carried out without a standardised process. Although technology development activities can be successfully completed without a standardised process, achieving successful results depends on individual skills (Richrath, Plano, & Nesbitt, 2016, p. 1). However, to increase the chances of success in technology development activities, organisations need more than just individuals' skills. Therefore, organisations are focusing more on business strategies and processes (Catlin, Scanlan, & Willmott, 2015, p. 1).

A clear definition of the research focus is crucial for addressing the research gap and enhancing the potential to generate new knowledge. Furthermore, clarifying the research scope contributes to a better understanding of the study and enhances its credibility. To this end, a comprehensive review of the literature was undertaken to examine studies that emphasise the importance of the field and to identify topics that have not previously been addressed. The study conducted by (Branscomb & Auerswald, 2002, p. 16) revealed that there is a substantial body of research on strategy, management, organisational motivation and financial issues related to technology development activities. Nevertheless, it was observed that research on the technology development process is scarce and that the number of documented studies is relatively limited. According to Carbonell, Rodriguez Escudero, & Munuera Aleman (2004, p. 83), studies on measuring the success of new products using the stage-gate evaluation approach are insufficient. According to Stern (2008, p. 132), the technology development process is long term and its results cannot be fully predicted in advance. A long period is required between the initiation of technology development activities and the achievement of clear results and impact. Therefore, there is a need for clear and precise information on how the technology development process takes place. A study conducted by PwC revealed that organic growth of organisations is more than twice as high as other growth models (mergers, acquisitions, etc.). Agreements such as mergers, acquisitions and partnerships is frequently to procure assets pertaining to research and development capabilities, intellectual property rights and products. Consequently, the utilisation of internal R&D activities is considered a pivotal factor in the growth models adopted by firms (Wobig, 2015, p. 1). Furthermore Richardson (2017, p. 3), stated that the lack of setting common priorities for the implementation of activities at the organisational level may make comprehensive decision-making and implementation difficult. The lack of an integrated decision-making and implementation mechanism hinders agility. It becomes difficult to make the right decisions to stop low-performing technology development activities and focus on high-performing activities. Finally, according to Kolossovski (2019), in the product development process, 4 out of every 7 product ideas are found valuable, 1.5 of them are attempted and only 1 of them is successful. This situation is important in demonstrating difficulties in development and commercialisation phases of product development process.

Furthermore, studies on research and development, product and innovation management, which are either directly or indirectly related to technology development, have been analysed within a broad conceptual framework. Carbonell et al. (2004), examined the relationship between the various dimensions of fit/unfit criteria and new product success throughout the product development process in 957 firms in the mechanical equipment, computer equipment, electrical machinery, electronic equipment, measuring instruments and motor vehicles and other transport equipment industries in Spain. The study involved 77 firms and found that the relative impact of the five dimensions of fit/unfit criteria on new product success variedvaries depending on the stage of the development process and technological innovation. Song & Montoya-Weiss (2001), developed a theoretical model in their study to examine the regulatory effect of perceived technological uncertainty on the new product development process. Günday (2007), examined the influence of firm structure, firm characteristics, firm strategy, sectoral conditions, and relationship factors on innovativeness. In the second stage of the study, the effect of innovation on firm performance was analysed.

The study presents evidence based on survey data obtained from 169 firms. The evidence indicates that innovation determinants exert a significant positive effect on the firm's innovative ability. Furthermore, innovativeness is an effective factor in both production and innovation performance. Ernst, Hoyer, & Rübsaamen (2010), investigated the effects of cross-functional collaboration between sales, marketing and R&D on the new product development process and performance in a new product development project in the highest-income enterprises in Germany. The findings of this study indicate that collaboration between sales and R&D is crucial for new product success, particularly during the concept and product development stages. Tekin (2016), investigated the impact of innovation knowledge and innovation management on innovation capabilities and new product success in 10 firms within the Turkish white goods sector. The findings indicated that innovation capability significantly influences product success. Guimaraes, Paranjape, & Walton (2019), examined the impact of organisational culture, competitive intelligence, technology management, innovation project management, and absorptive capacity on new product development success. According to their findings, factors other than strategic leadership significantly influence the success of new product development. Meier & Kock (2022), examined the impact of agility in the organisation of research and development (R&D) units within an industrial firm operating globally in the field of mechanical engineering across more than 80 countries. In this context, they developed a six-dimensional scale, including agility culture, customer integration, autonomy, an iterative work method, cross-functional capabilities, and a horizontal hierarchy. The developed scale demonstrated a direct correlation between agility in R&D organisation and front-end success.

A comprehensive review of the existing literature provided valuable insights into gaps in the literature. This analysis has also helped us identify specific areas where our current research can make meaningful contributions. The reviewed existing studies provide a summary of the various factors and methodologies related to technology development, innovation product development processes in different industries and contexts. These studies deepen existing knowledge about technology development, innovation and product development processes, while also highlighting areas for further unexplored research. Previous studies have typically examined the technology development process as part of innovation and product development processes. However, as Kolossovski (2019) also highlighted, the probability of success decreases rapidly as the process progresses. The evaluation of innovation or product development process alone does not provide sufficient information about the technology development process. Therefore, it is necessary to place greater emphasis on the deepening of the technology and innovation literature, with a focus on the entire process from idea generation to the transition from technology to product/production. In previous studies, industries with different levels of technology (e.g., mechanical, computer equipment, electrical machinery, biotechnology, chemicals, and pharmaceutical industries) were examined separately. There is a need for evidence on the applicability of a comprehensive model that encompasses the practices related to technology development processes in industries with high, medium-high, medium-low, and low levels of technology. Finally, previous studies have generally focused on performance factors related to market and financial success. There is a need for evidence on process performance factors, including technical success, timing, and budgeting to determine whether the process has been successfully implemented.

In this context, a three-stage approach was used to determine the scope of the research. The first of these, as shown in Figure 1, is the internal R&D activities among the technology acquisition and development methods.

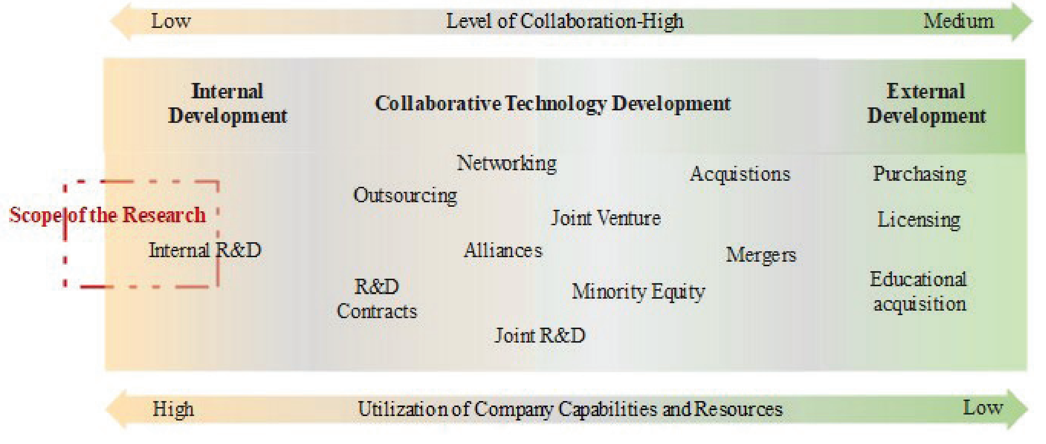

Figure 1. The Technology Acquisition Model

(Adapted from the studies of Chiesa, Frattini, Lazzarotti, & Manzini, 2009; Gallardo, 2013)

The second stage in determining the scope of the research is related to defining the evaluation process. Technology development projects/programmes are a process that involves inputs, activities, outputs, outcomes and impacts. The evaluation was conducted within the framework of a methodology that considered the factors shown in Figure 2. Therefore, the scope of the research was conducted within the framework of a methodology that considers the evaluation factors shown in Figure 2. The inputs provide information about the firm's characteristics. Activities refer to actions intended to obtain desired outputs by utilising resources. The immediate and tangible outcomes generated by activities must be measured for long-term results and impacts to achieve lasting benefits (Griffin, 1993, p. 115). In the evaluation approach, the relationship between inputs and outputs is expressed as efficiency the relationship between objectives and outcomes is expressed as effectiveness, and the relationship between needs and impact is expressed as benefit and sustainability. Different purposes can be associated with evaluation (Arnold, Åström, Glass, & Scalzi, 2018, p. 15). The purpose of this study was to determine the level of goal achievement depending on the implementation level of the activities.

The final stage in determining the scope of the research is related to the level at which the evaluation will be conducted. "*Organisational level focuses on organisational structures, processes, resources, and management issues*" (Bolger, 2000, p. 4) . At the organisational level Figure 3, evaluation addresses the overall performance factors and capabilities of the organisation in fulfilling its tasks. These factors refer to internal regulations, processes, and plans that determine how individuals' abilities should be utilised and directed (United Nations Development Programme, 2008, pp. 6–7). Assessing capacity at the organisational level addresses issues at the organisational level. However, it also influences and is directly influenced by individual-level as well as sectoral and environmental interactions (Bolger, 2000, p. 4).

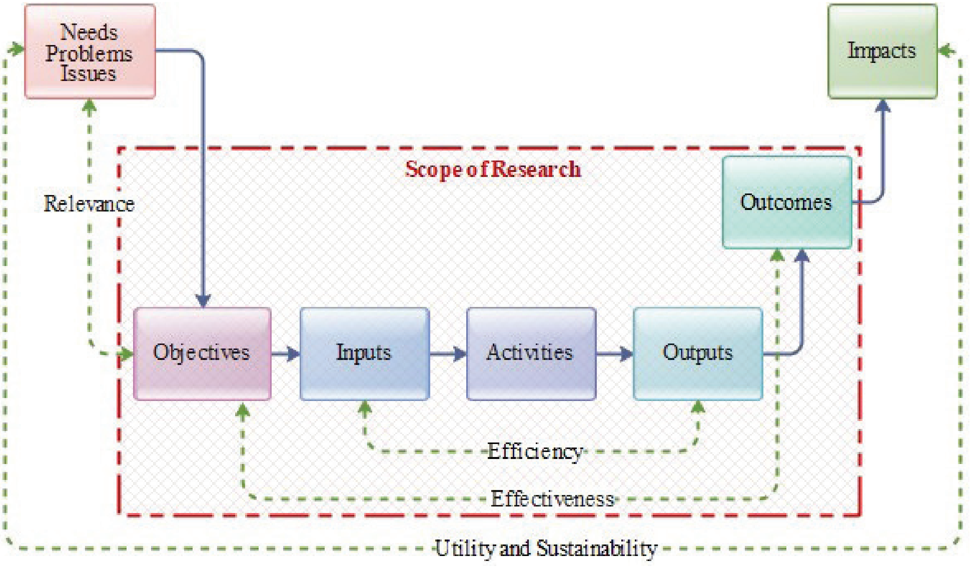

Figure 2. Theory of Evaluation (Change) (Arnold et al., 2018)

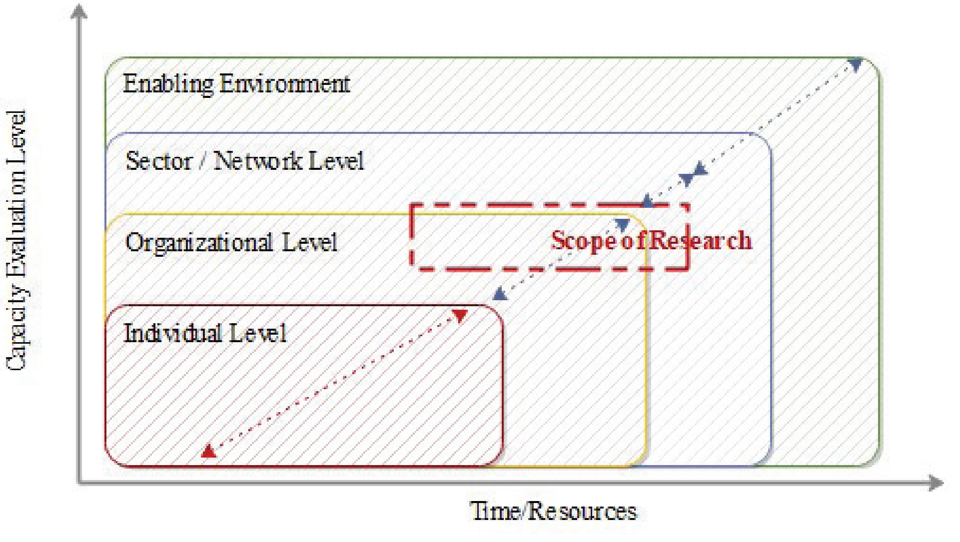

Figure 3. Capacity Development: Conceptual Framework (Bolger, 2000)

Considering the scope of the study and the methodology employed, it is inevitable that there will be some limitations. The first is that this study focuses solely on internal technology development activities within the firm. Therefore, the proposed model does not provide evidence of its suitability for technology acquisition from external sources and technology development processes through collaboration. In addition, it presents information regarding outputs and outcomes achieved through inputs and activities. Finally, despite considering privacy principles related to the obtained data, research outcomes may not fully reflect the actual situation because of participant bias.

The aim of this study is to develop an evaluation model for measuring the standard process and performance of technology development activities, which will serve as a reference for conducting such activities. The model is characterised by a structure consisting of four dimensions: technical research, commercial research and performance. If the proposed model is successfully implemented, all personnel involved in the process will perform their activities based on predictable and evidence-based decisions. Once the proposed model is fully implemented, resources are efficiently used, ensuring minimal deviations in cost, time, and technical requirements. As a result, the success rate increased.

In line with this objective, the study relies on evidence from managers and experts working in research and development, technology development and innovation in the top 500 businesses with the highest R&D expenditures in Türkiye.

Method

This study was conducted in accordance with the positivist paradigm. The phenomena examined in this research were approached objectively in the context of causal relationships, in accordance with the conceptual framework. In this context, a quantitative methodology was employed in the study to examine phenomena objectively within the framework of causal relationships. The study has both exploratory and descriptive aspects. The data in this study were collected using the survey method.

Verbal informed consent was obtained from all participants before the study and the ethics committee approval of this study was obtained from Ethics Committee for Social and Human Sciences Research at Fırat University. (Date: 14.11.2019; Number: 5).

In this study, the use of quantitative methods aims to:

1. Enable the generalisation of findings to the population by measuring the implementation level and frequency of a formal and structured technology development process in the selected sample.

2. Provide evidence to identify and justify fundamental relationships between variables.

3. Ensure obtaining objective results through statistical tests (Sun, 2012, p. 7; Walwyn & Chan, 2019, p. 14)

Factor and Item Acquisition Processes

Technology development processes consist of a series of activities that occur from the idea stage to the market launch stage (Pleschak, 1997, p. 11). Technology development processes involve defining each stage and organisational structure, standardising activities accordingly (Möller, Menninger, & Rober, 2011, p. 6). The fundamental idea of technology development process is to ensure that businesses allocate their limited resources to the right projects, thereby minimising technology development costs, development time and deviations in technical performance requirements. By following these processes, businesses develop solutions to the challenges they encounter and achieve success. Although each business may have unique processes and activities, these processes and activities often do not take place within a universally accepted framework (Pleschak, 1997, p. 11). Technology development processes are designed in different ways but with the same purpose in mind. The existence of various approaches creates uncertainty for implementers in selecting the appropriate approach (Ajamian & Koen, 2002). Technology can be aimed at meeting an existing need; however, it can also result from entirely new ideas that can create novel requirements (Stern, 2008, p. 11). The purpose of business processes is to ensure that tasks performed at the organisational level are performed in a systematic manner, in a sequence of consecutive steps, and following a specific methodology (Dumas, La Rosa, Mendling, & Reijers, 2018, p. 9).

In businesses with a well-organised structure, an integral part of a process and are executed in a suitable manner according to this process. It should be noted that this process is a comprehensive set of activities that enable businesses to transform inputs through various stages into outputs to achieve their objectives (Çetindamar, Phaal, & Probert, 2016, p. 2).

A standard process ensures clarity and consistency regarding where, how, and when each stage and activity constitutes a business process in a business will be executed. In organisations with structured processes, even if the same task is assumed by different individuals over time, it is expected that these tasks will be performed in the same manner (Robbins, & Barnwell, 2006, p. 111). Activities in a standard technology development process serve as guiding principles to support effective and efficient technology development efforts. This process focuses on best rather than mandatory rules (United States Department Of Energy, 2007, p. 4). The objective is to identify and synchronize what needs to be done at different stages of the process and by different working groups to align with common goals. However, a standard technology development process does not contain information about how it should be implemented and by whom, as it lacks an implementation plan feature (Doerry, 2010, p. 22) .

However, a standard technology development process does not contain information about how it should be implemented or by whom, as it lacks an implementation plan feature.

The scale development process was conducted in four stages. In the first stage, potential scale items and factors were determined by utilizing activities and stages obtained from normative technology development models. In the second stage, the scope validity of the scale was tested, and in the final stage, empirical evaluations were conducted.

Establishing a conceptual foundation is crucial to the scale development process. The conceptual foundation guides the researcher on what should be included in the developed model. Additionally, it defines the boundaries of the model, allowing the researcher to focus and reduce ambiguity in scope (Carpenter, 2018, p. 13). In the process of scale item generation, either inductive or deductive methods or a combination of both, can be applied. In the deductive method, items are created by scanning relevant literature and existing scales in the field. On the other hand, in the inductive method, items are generated based on information and qualitative data obtained through focus groups and individual interviews (Boateng, Neilands, Frongillo, Melgar-Quiñonez, & Young, 2018, p. 1).

In this study, the deductive method was used during the item development phase. For this purpose, 32 normative models widely accepted in the literature were analyzed. The selected normative models comprise both academically based models and models applied in the public and different industries. The activities and stages included in these normative models were classified by thematic analysis method. Normative models consist of different numbers of stages and activities depending on the level of detail. The identified common themes form a potential scale item pool. During the creation of the item pool, all normative models were examined, and a comprehensive approach that considered the activities agreed upon in the current studies was adopted. Additionally, to measure the performance of the process, relevant items (pertaining to performance) were obtained by referring to the literature.

Table 1
*Thematic Analysis of Normative Model Items**

Factors	Items	References
Business Research	Market Potential	(Schulz, Clausing, Fricke, & Negele, 2000), (Loutfy & Belkhir, 2001), (Cooper, 2006), (Kausch, 2007), (Canez, Puig, Quintero, & Garfias, 2007), (Gaubinger & Rabl, 2014)
Technical Research	Technology Development Capability	(Myers & Marquis, 1969), (Schulz et al., 2000), (Loutfy & Belkhir, 2001), (Ajamian & Koen, 2002), (Cooper, 2006), (Lind, 2006), (Whitney, 2007), (Crill & Siegler, 2017), (Kausch, 2007), (Gaubinger & Rabl, 2014),

Factors	Items	References
Development	Protection of Technology	(Canez et al., 2007), (Myers & Marquis, 1969), (Office of Technology Assessment (OTA), 1982), (United States Government Accountability Office (GAO), 2006), (Cooper, 2006), (Kausch, 2007), (Miller, Bustamante, Roesch, Boshell, & Ayuso, 2015)
Performance	Compliance of Technical Success with Budget and Time Schedules (Earned Value Approach)	(Moser, 1985), (Chiesa et al., 2009), (Association for Project Management, 2013)

* Partial analysis results have been included

The number of factors was determined considering the number of stages in the normative models, which are partially presented in Table 2. The existing technology development models were created with 2 to 7 stages. In most models, a 4-stage structure was predominantly used.

Table 2
*Stages of Normative Technology Development Process**

Stages	Number of Stages	References
1-Idea Generation, 2-Project Planning, 3-Technology Concept, 4-Technology Development	4	(Gaubinger & Rabl, 2014)
1-Invention, 2-Project Scope, 3-Technology Concept Development, 4-Technology Development, 5-Technology Optimization, 6-Technology Transfer	6	(Caetano, Araujo, Amaral, & Guerrini, 2011)
1-Explore, 2-Development, 3-Technology Transition	4	(United States Government Accountability Office, 2006)
1-Basic Research, 2-Applied Research, 3-Development	3	(Bronzino, 1992)
1-Target İdentification, 2-Lead Discovery 3-Preclinical Trial 4- Clinical Trial 5-Approval	5	(Romasanta, Van der Sijde, & Van Muijlwijk-Koezen, 2020)

* Partial analysis results have been included

After identifying the stages and activities, scale items and factors were derived within the context of the model using an interpretive approach. To establish a clear, comprehensible, and consistent conceptual framework for the intended construct to be measured, it is necessary to define each factor of the scale. For this purpose, descriptions of technical and commercial research, development, and performance factors have been provided.

New technology development is a discovery process involving technical and business research activities that require a search for new knowledge. This situation arises from the presence of broad objectives and significant uncertainties at this stage (Sheasley, 1999, p. 52). In these stages, even simple changes in assumptions can lead to significant financial and technical risks. Allocating business resources to a technology initiative may result in neglecting other initiatives (Day, 2008, p. 52). A successful research phase can prevent interruptions and the emergence of conceptual and outcome changes within the process (Harmancioglu, McNally, Calantone, & Durmusoglu, 2007, p. 422). The technical and business research factor, which examines technology, markets, and financial matters, represents the initial stages of the technology development process. It is designed to define the stages consisting of exploratory activities. These two factors consist of activities from generating technology ideas to determining the characteristics of technology, including conceptual development stage. Activities that involve in-depth examination and analysis related to the market, competition, and customers. The technical research factor consists of activities that analyse the feasibility of technology ideas, such as its suitability, feasibility, implementation possibilities, intellectual property status, and firm capabilities. Effective research activities assist in early termination of unpromising and unfeasible ventures.

The development phase defines activities aimed at practical advancement of technology. Activities during this stage are based on information obtained during the technical and business research stages. The technology requirements, working principles, and physical characteristics are defined. Additionally, the feasibility of the technology is demonstrated through laboratory and real-world application environments, and outputs that can be subject to intellectual property rights are generated. These activities also encompass processes related to the transition of the technology to the final product/production stage.

The final factor in the model is related to measuring the performance of the process. Performance refers to measuring how successful a task is being executed. The process includes decision-making, planning, problem-solving, monitoring interactions and evaluation activities. If the process is carried out successfully, the business shows good performance and becomes successful (Lusthaus, Adrien, Anderson, Carden, & Montalván, 2002, p. 76). The aim of this factor is to assess the business's success and performance during the technology development process. Objective measurements are necessary to ensure the success of the technology development process and the accuracy of decisions. Accurate analyses can be conducted using proper measurements. These accurate analyses by providing a foundation for sound decisions, facilitate the achievement of objectives (Milbergs & Vonortas, 2006, p. 2). At the organisational level, measuring performance can be conducted to encompass one or more criteria, such as effectiveness, efficiency, compliance, and financial feasibility (Lusthaus et al., 2002, p. 76). In this study, the identified performance factor was derived from criteria related to measuring operational outcomes. These criteria include technical performance (product's technical functionality and quality), development cost, and development time. The success of the process is evaluated based on meeting all these criteria at the highest level (Tatikonda & Rosenthal, 2000, pp. 76–77).

Research Population and Sample

The aim of this study is to examine the technology development process at the firm level. Therefore, implementing the sample in businesses where technology is developed will ensure line with the research purpose. For this purpose, the universe of research is constituted by the top 500 businesses in Türkiye that made the highest R&D expenditures in 2020. The R&D 500 firm list is based on the R&D data declared by the top 500 businesses in Türkiye in terms of export ranking, businesses disclosing R&D data on the Public Disclosure Platform, and businesses approved by the Ministry of Industry and Technology of the Republic of Türkiye as R&D centres. However, some businesses' names were not disclosed, yet they were included in the ranking, resulting in a total of 472 businesses comprising the research universe (Turkishtime, 2021, p. 26). The research employed the scale development methodology. Expert opinions were sought for content validity. The survey method was utilized for exploratory and confirmatory factor analyses. Survey data were collected through Google Forms during the period from November 2021 to May 2022, based on the responses of R&D, innovation, technology unit managers, and experts. During this period, data were collected from the same research population in two stages at different time points. The data collected in the first stage were intended for exploratory factor analysis, while the data from the second stage were gathered for confirmatory factor analysis. Analyzing issues such as missing data, outlier values, and multicollinearity was conducted. In total, 625 responses were used in the study. The distribution of responses was examined based on the classification established by the OECD in 2001 according to R&D intensities. Accordingly, 180 respondents (28.80%) were from the high-tech industry, 284 (45.4%) from the medium-high-tech industry, 94 (15.04%) from the medium-low-tech industry and 67 (10.72%) from the low-tech industry.

Findings

Based on the information obtained from Tables 1 and 2, a final structure consisting of 26 items and 4 factors was established. To assess the scope validity of this structure, support was sought from an evaluation group consisting of 8 experts. The structure was evaluated by an expert group comprising 2 experts in scale development, 4 experts working in the industry, and at least 2 academics who have received national or international project support. The number of questions in the initial survey form was excessive and included repetitive structures. Following the final evaluation, questions were removed from the survey that were deemed to have low clarity, terms that did not accurately define the expression, statements creating uncertainty that would prevent participants from understanding correctly, and questions that were deemed not to directly contribute to the main objectives of the survey. The Lawshe technique was applied to measure the validity of expert judgments. As a result of the expert panel evaluation, a content validity value of 0.75 was measured.

A good empirical study should have two main characteristics. These are the design of the researched model and the selection of relevant target groups approved by the participants. Kaiser-Meyer-Olkin (KMO) is a measure of sampling adequacy used in factor analysis. After the analysis, the KMO value was determined to be 0.909. Since this value is above 0.6, it can be stated that the data is sufficient for factor analysis, providing a solid basis for conducting the analysis. The obtained value indicates that the suitability of the variables with the sample is excellent. The Bartlett's sphericity test was conducted, and the result was found to be significant with a p-value of 0.000 ($p < 0.05$), indicating that the assumption of sphericity has been met. This finding indicates that there is a significant correlation among the variables. Furthermore, the variables themselves show a certain level of correlation. They also exhibit high levels of correlation with other variables. Thus, the suitability of the obtained data for factor analysis was observed (Hair, Black, Babin, & Anderson, 2019, p. 136).

In the initial stage of scale development, a literature review and content validity assessment led to the decision to select a 4-factor structure. In determining the optimal number of factors, an approach that considered factor determination techniques along with a review of relevant literature was employed. In addition to the mentioned approaches, (Carpenter, 2018, p. 37) has suggested examining 2-factor and 6-factor structures when 3, 4, or 5 factor structures are obtained. This recommendation implies that, even if the initial 3, 4, or 5-factor structures seem reasonable, exploring alternative factor solutions can potentially identify a better factor structure. As a result of the statistical analysis, a 4-factor structure was obtained. The obtained structure was evaluated for 2 to 6 factors, and it was decided that the most suitable factor number is a 4-factor structure. Consequently, a structure consisting of 4 factors and 20 items was obtained.

Table 3
Multicollinearity Analysis

Factors	**Tolerance Value**	**Variance Inflation Factor**
Business Research	,463	2,159
Technical Research	,394	2,540
Development	,429	2,328

Dependent Variable: Performans

To determine whether the results obtained from exploratory factor analysis are sample-specific or generalizable to the population, confirmatory factor analysis was conducted in the second stage for cross-validation using the data obtained. During the confirmatory factor analysis stage, multiple collinearity analyses, validity-reliability tests, goodness of fit, and findings regarding the final structure of the model were obtained. When the VIF value is less than 5 and the tolerance value is greater than 0.2, multicollinearity problem does not occur (O'brien, 2007, p. 685). The analysis results for the presence of multicollinearity using VIF (variance inflation factor) and tolerance values are presented in Table 3. It was observed that the tolerance and VIF values are in accordance with the threshold values, which indicates that there is no multicollinearity problem.

To ensure discriminant validity, heterotrait-monotrait (HTMT) value should be below the strict threshold of 0.85 and the acceptable threshold of 0.90 or 1.00 (Gaskin, Godfrey, & Vance, 2018, p. 10). As seen in Table 4, values related to the model are below the acceptable threshold, indicating that discriminant validity has been achieved.

Table 4
Heterotrait-Monotrait (HTMT) analysis

Factors	Business Research	Technical Research	Development	Performance
Business Research	1			
Technical Research	,887			
Development	,850	,903		
Performance	,702	,778	,798	1

To establish convergent validity, it is sufficient for the average variance extracted (AVE) value to be greater than 0.5. However, even if the AVE value is less than 0.5, convergent validity can still be achieved if the composite reliability (CR) value is greater than 0.6 (Safiih & Azreen, 2016, p. 43). Accordingly, within the scope of convergent validity, the AVE and CR values were calculated for each factor, as presented in Table 5. Comparing the calculated AVE and CR values with the threshold values, it is concluded that the structure shows convergent validity.

Table 5
Validity and Reliability Results

Factors	AVE	CR	Cronbach's Alpha
Business Research	,491	,852	,825
Technical Research	,651	,848	,812
Factors	**AVE**	**CR**	**Cronbach's Alpha**
Development	,517	,882	,841
Performance	,719	,911	,817

To determine the reliability level, both composite reliability and Cronbach's alpha values were examined. In structural equation modelling, composite reliability is preferred over Cronbach's alpha for assessing reliability. In this case, for reliability, the Cronbach's alpha value should be at least 0.7, and the composite reliability should be above 0.6 (Hair et al., 2019, p. 768). As shown in Table 5, both the composite reliability value and Cronbach's alpha value are above the specified threshold, indicating that reliability has been achieved for the entire structure. This suggests that the data used in the analysis are reliable and consistent and provide a strong foundation for the interpretation and conclusions of the study.

The model fit indices are used to assess the level of fit between the model and the data used (DiStefano & Hess, 2005, p. 227). The model fit indices are presented in Table 6. As seen in the table, the fit index values of the model fall within the range of reference values, indicating that the model fits the data appropriately.

Table 6
Model Fit Indices

Model Fit indices	Obtained Value	Recommended Value
Chi-square Test ($\chi^{2/sd}$)	2,983	$1< \chi^{2/sd} < 3$
Root Mean Square Error of Approximation (RMSEA)	0.07	RMSEA < 0.08

Model Fit indices	**Obtained Value**	**Recommended Value**
Standardised Root Mean Square Residual (SRMR)	0.026	0.00≤SRMR≤0.10
Goodness-of-Fit Index (GFI)	0.903	0.90≤GFI≤1.00
Adjusted Goodness-of-Fit (AGFI)	0.857	0.85≤AGFI≤1.00
Normed Fit Index (NFI)	0.901	0.90≤NFI≤1.00
Comparative Fit Index (CFI)	0.932	0.90≤CFI≤0.97

A model consisting of technical research, business research, development, and performance factors was obtained. The process components of the model are formed by technical research, business research, and development factors, and these factors play a determinant role in the performance factor, which is the outcome component. The structural representation of the model is shown in Figure 4.

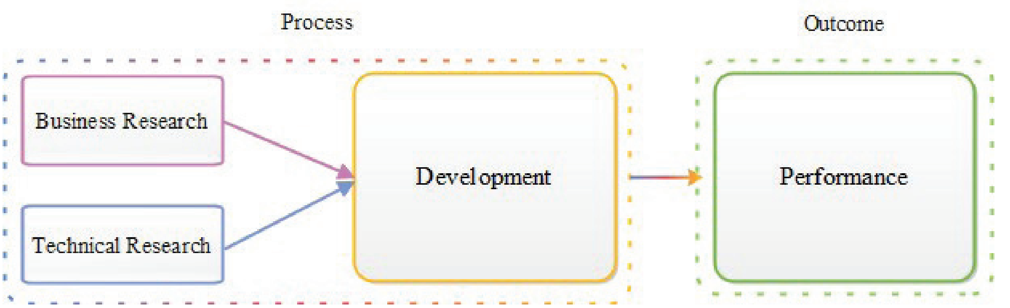

Figure 4. *Conceptual Model of Scale*

The factor loadings obtained for each item through exploratory (EFA) and confirmatory factor analysis (CFA) are provided in Table 7.

Table 7
Item Loadings in EFA and CEFA

Factor	**Items**	**EFA**	**CFA**
Business Research	The current state of the market is evaluated.	,77	,82
	The market potential is evaluated.	,77	,83
	The competitive situation is evaluated.	,80	,77
Technical Research	The level of openness to newness and improvement of the technology idea is evaluated.	,66	,64
	The suitability of the technology idea to scientific and technical approaches is evaluated.	,71	,68
	The restrictions imposed by existing patents on the development of the new technology are evaluated.	,66	,70
	The organization’s technology development capabilities are evaluated.	,70	,73
	The application area and potential beneficiaries of the technology are evaluated.	,63	,72
	The intellectual property protection level for the technology is evaluated.	,76	,73

Factor	Items	EFA	CFA
Development	The technology is tested experimentally inin a laboratory environment for technical, performance, and functionality aspects.	,76	,68
	The technology is tested for technical performance and functionality in a real-world application environment.	,74	,73
	Responsible teams are formed to transition from technology to product development/ production.	,68	,74
	The maturity level of the technology is evaluated for its transition to the product stagep-roduction.	,65	,80
	Tests are conducted with potential beneficiaries (end-users), and feedback is collected.	,63	,65
	Evaluations regarding scaling up are carried out.	.64	.76
	Activities are carried out for the intellectual property protection of the technology.	.66	.66
Performance	The level of completed work in technology development projects is aligned with the timeline.	,86	,84
	The cost of completed work in technology development projects aligns with the planned budget.	,79	,87
	In technology development projects, technical performance aligns with the prediction.	,70	,85
	In technology development projects, technical success aligns with the budget and schedule.	,85	,83

Results and Discussion

This study focuses on the characteristics of standard technology development processes. This section defines the standard technology development process, determine the level of its implementation, and assess its impact on process performance. The proposed model evaluates the implementation of necessary activities for standard technology development processes, their level of implementation, and their impact on process performance. This study is built upon the assumption that the top 500 businesses in Türkiye, which spend the most on R&D, have implemented a standard technology development process in some way and that this implemented process has made a positive contribution to process performance. Technology development is a long-term and complex process, consisting of numerous critical decisions and activities. However, previous research has predominantly focused on the ideation phase, organisational attitudes, behaviours, culture and leadership. An approach explaining the relationship between process implementation and performance, and how process performance should be measured, has not been developed. Alongside obtaining results regarding whether the standard technology development process works or not, the study has also provided answers to the questions of why and how. The impact of the technology development process on operational activities and their operational outcomes has been analyzed, and the standard technology development process has been conceptualised and supported using empirical results.

The development of new technology is a discovery process involving technical and commercial research activities that require new knowledge. A successful research phase can prevent interruptions and changes in concepts and outcomes during the process (Harmancioglu et al., 2007, p. 422). There are strong connections between marketing research and both engineering skills and R&D, which affect product outcomes (Sun, 2012, p. 7). Market, business opportunities, and competitive conditions play an important role in facilitating technology management (Sweeney, 1990, p. 9). Market-oriented behaviours facilitate strategy implementation and have a positive impact on performance (Dobni & Luffman, 2003, p. 583). Our findings, which are in line with this perspective, provide evidence supporting the necessity of incorporating factors associated with technical and business research into the technology development process.

The accuracy and reliability of early-stage (research) information shape subsequent technical stages (Frishammar, 2005, p. 16). The process is completed successfully when the required criteria are met at each stage. A process that is successfully completed shows good performance and achieves success (Lusthaus et al., 2002, p. 76). Decisions regarding product content and project scope have strategic importance due to their impacts on project performance. There is a relationship between decisions regarding the scope of the product to be developed, and project scope, and project performance. The transition between fundamental and applied research and product development processes is particularly important. Activities related to the selection, development, and transition of technology have a significant impact on product development performance (Iansiti, 1995, p. 260). The findings of this study support the information presented in previous studies. The evidence obtained from this study shows that the research stage impacts the development stage. Additionally, in the technology development process, the stages of technical research and development play a decisive role in performance. However, it is not possible to mention that business research has an impact on performance. Adequate implementation of activities related to the business and technical research stages leads to a positive impact on the development stage. This situation also contributes to the technology development initiative to achieve the desired level of success from an operational perspective.

From the perspective of the literature, specialisation in technology development processes is important due to the field's ongoing significance and potential to play an even greater role. In this regard, the study will also make a significant contribution to the expansion of the technology development process and its related literature. Moreover, it possesses comprehensive features by examining thirty-two normative models that directly reference technology development and technological innovation, which serve as the basis for the proposed model. Another important finding of this study is the evidence that technology development initiatives can be evaluated in the context of operational activities, and their performance can be measured.

From a practical perspective, the evidence obtained suggests that businesses should adopt a standard technology development process. The developed model will benefit technology development initiatives conducted by businesses at both national and international levels, across different industries, and of various sizes. Successful completion of the technology development process provides information about the challenges encountered throughout the process. The results obtained from the full implementation of the proposed model will help address the gaps related to the reasons for shortcomings in technology development processes by comparing them with previous practises. In this way, the proposed model can contribute to improving processes by learning from past applications.

In conclusion, structured processes are essential for businesses to shorten the technology development cycle, increase success rates, foster collaboration, and promote knowledge sharing while ensuring proper allocation of resources. By identifying and implementing these structured processes, more successful outcomes can be achieved. However, even if businesses have all the necessary capabilities, achieving perfect implementation of the process may not be possible.

Further Work

Challenges in technology development processes persist. The primary focus of process improvement is the decisions made and the extent to which employees can implement them. Researchers should always consider these factors. Each stage from idea generation to process performance measurement should be approached using different innovative approaches. Performance requirements, especially concerning technology development processes, should be examined using different factors and criteria. Even if a good process exists throughout the organisation, the impact of the relationship between team flexibility and empowerment required (Krishnan, 2013, p. 144) by team members, which is inherent in the nature of technology development, and the role of the leadership approach should be examined in the process.

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