A Framework of Performance Efficiency Measurement in Technology Transfer Office (TTO) for Acceleration of Commercialization Technology

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Abstract
Technology commercialization is a means of utilizing research result technology in both production and consumption activities so that researchers can benefit from these activities. In many cases, many research technology products fail to enter the market due to the valley of death. This obstacle usually occurs in the transition process between technological development and technology commercialization. Therefore, critical action is needed to accelerate the commercialization of technology so that the commercialization potential of research results does not fall into the valley of death. Higher education institutions are expected to take part in this process to accelerate the transfer of new technology products to the market. To manage the commercialization of new technology, it is necessary to establish a Technology Transfer Office (TTO). The TTO has a key role in providing structural links between universities and industry. To achieve this, this study becomes a preliminary study to design a framework for measuring the performance efficiency of a TTO. Several research models have been developed to measure efficiency. The model developed in this study refers to the goldsmith commercialization model and TRL. The Goldsmith model was chosen as the reference method because this model is specifically designed to analyze the strategic and systematic commercialization of technology. TRL was chosen as an assessment of the readiness of research results using the Techno-Meter approach. These two models are combined to design a framework for measuring the efficiency of TTO performance for accelerating technology commercialization.

Keywords
Goldsmith Commercialization, Performance Efficiency Measurement, Technology Transfer Office (TTO), and Technology Readiness Level (TRL)

1. Introduction
Down streaming of research or technology results comes from innovations originating from research activities (technology push), ideas or problems in society (market pull) which are then commercialized to create innovative product-based business organizations that are competitive for the nation and prosper the people. Organizations can be

formed by the university itself (spin-off), or external organizations that work together as distributors of innovative products through a partnership scheme (license/royalty).

The general challenges of innovation are usually caused by gaps between academic and industrial research (Chirazi et al, 2019 and Bhusan, 2015), this is commonly referred to as the valley of death. Valley of death is when innovation fails to enter the market or does not sell in the market so that the product dies and does not develop. However, this challenge can be overcome if there is a collaboration between academia and industry, where the industry needs solutions to existing problems and academics to want findings or innovations that are useful for society with these findings/innovations entering the market and being sold (Kaiser, 2014).

Activities that increase the value or reduce costs integrate products or services are called commercialization (Diharjo et al, 2014). Whereas the commercialization of technology is defined as "moving technology to a favorable position" (Siegel et al, 1995), meaning that technology is developed in such a way that it reaches a point where technology can be applied to a production or consumption activity that generates profits for its discoverers (Diharjo et al, 2014). In this sense, an innovation/research result in a university requires the commercialization of technology so that the technological innovation found can enter the market.

Therefore, critical action is needed to accelerate the commercialization of technology so that the commercialization potential of research results does not fall into the valley of death. Universities are expected to take part in this process to accelerate the transfer of new technology products to the market (Sutopo, 2015, Sutopo, 2019). According to Sutopo et al (2019), there must be a system that connects technology development and commercialization to ensure the potential for commercialization of research results does not fall into the valley of death. Figure 1 shows an overview of the valley of death in the technology commercialization process.

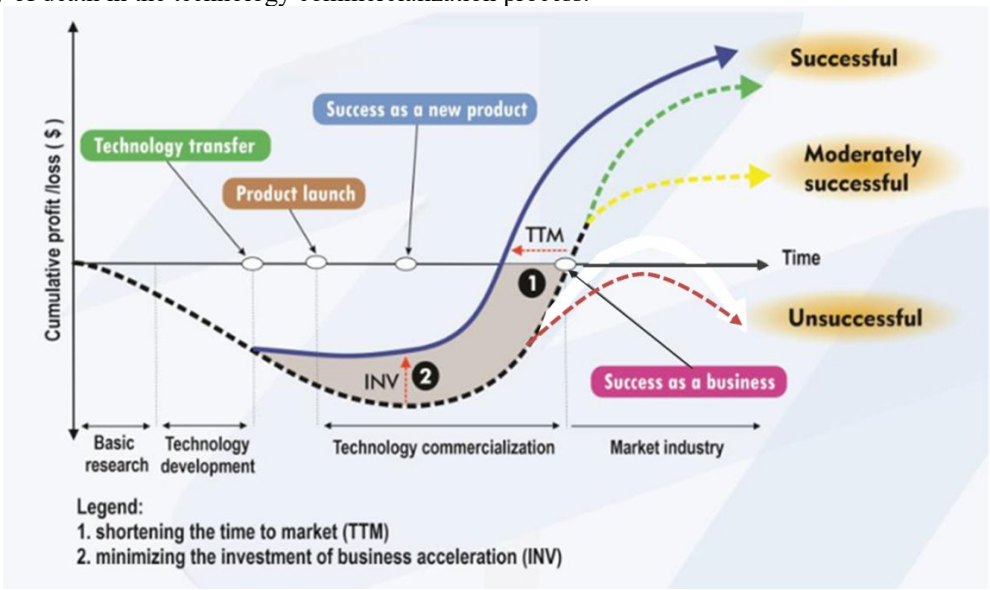

Figure 1. Picture of the Valley of Death in Technology Commercialization

Technology commercialization begins with basic research activities and technology development to technology transfer, then the next stage is the commercialization process towards product launch, the last stage is the commercialization process until it succeeds in becoming a business (Figure 1). So that efforts to increase the commercialization of higher education research results have been carried out in almost all universities in the world by establishing a technology transfer office (TTO) to manage the commercialization of new technology (Siegel et al, 2007, Dalmarco et al, 2011, Vinig and Lips, 2015, Rogers et al, 2000, Phan and Siegel 2006, Harlow, 2017, DeVol et al. 2017). A technology transfer office (TTO) is a type of organization that assists research organizations in managing their intellectual assets in a way that facilitates their transformation into benefits for society (Carlsson, 2002). According to Tunca and Kanat (2019), Technology Transfer Offices (TTO) have a key role to provide structural linkages between universities and industry, a collaboration model that suits their specific needs as well as simplified tools for all possible collaboration models.

The general role of the TTO includes building relationships with companies and community actors, generating new financial support from sponsored research or consulting opportunities, providing assistance in all areas related to entrepreneurship and intellectual property (IP), facilitating the formation of university-linked companies that utilize the university. Technology (start-up) and/or university resources (spin-off) to increase prospects or further development and generate net royalties for university technology and collaborating partners. The university's technology commercialization strategy is formulated by the technology transfer office (TTO). The strategies that the TTO can undertake in carrying out its role include having physical facilities to support technology commercialization, mentoring and coaching activities, marketing and business networks, financial support, and internal regulations of the university itself. The efficiency of the strategy that has been implemented by the technology transfer office (TTO) in each university needs to be measured. As an effort, a performance efficiency measurement method is needed that can provide information about the acceleration of commercialization in higher education. The results of measuring the efficiency of the performance of the accelerated commercialization can then be used as a reference for other universities to formulate strategies for accelerating the commercialization of research results.

Goldsmith's commercialization model is a model that integrates technical aspects, market, and business process elements for commercialization into a sequential matrix of concurrent activities. This commercialization model covers the entire process, from the first idea, through the development, creation, and start-up of a spin-off company and then an exit strategy for inventors and investors (Diharjo et al., 2014; Goldsmith, 1995; Goldsmith, 2003). The Goldsmith model was chosen as the reference method because this model is specifically designed to analyze the strategic and systematic commercialization of technology.

To support the goldsmith model, it is necessary to evaluate research results at the TTO to consider the value and impact of all research outputs (including data sets and software), in addition to research publications. Also, consider various measures including the impact of qualitative indicators on the impact of research, such as influence on policy and practice (BPPT, 2012). So that the TRL method was chosen as an assessment of the readiness of research results using the Techno-Meter approach in this study. These two models are combined to design a framework for measuring the efficiency of TTO performance for accelerating technology commercialization.

2. Literature Review

2.1 Goldsmith Commercialization Model

Goldsmith's commercialization model is a model that integrates technical aspects, market, and business process elements for commercialization into a sequential matrix of concurrent activities. This commercialization model covers the entire process, from the first idea, through the development, creation, and start-up of a spin-off company and then an exit strategy for inventors and investors (Diharjo et al., 2014; Goldsmith, 1995; Goldsmith, 2003). Goldsmith (2003) describes it as a tactical model designed as a framework to help develop progress measures, identify information and technical assistance needs, project development costs, and estimate financing needs. The combination of these three phases and aspects forms the matrix shown in table 1.

Table 1. Goldsmith Commercialization Model

	Technical	Market	Business
Concept Phase			
Stage 1 Investigation	Step 1 Technology Analysis	Step 2 Market Needs Assessment	Step 3 Venture Assessment
Development Phase			
Stage 2 Feasibility	Step 4 Technical Feasibility	Step 5 Market Study	Step 6 Economic Feasibility
Stage 3 Development	Step 7 Engineering Prototype	Step 8 Strategic Market Plan	Step 9 Strategic Business Plan
Stage 4 Introduction	Step 10 Business Start-Up	Step 11 Pre-Production Prototype	Step 12 Market Validation
Growth Phase			
Stage 5 Growth	Step 13 Production	Step 14 Sales and Distribution	Step 15 Business Growth
Stage 6 Maturity	Step 16 Production Support	Step 17 Market Diversification	Step 18 Business Maturity

Source: NBDC (2018)

2.2 Technology Readiness Level (TRL)

Assessment of the readiness of research results is a process that involves many actors in research institutions, universities, and considers various data. The purpose of assessing research results is to consider the value and impact of all research outputs (including data sets and software), in addition to research publications. Besides, consider various measures including the impact of qualitative indicators of research impact, such as influences on policy and practice.

In this study, the assessment of the readiness of research results was approached by the Techno-Meter concept developed by BPPT. The assessment of research results based on the Techno-Meter concept is described based on the TKT indicator which is depicted in Figure 2.8. Each indicator describes the level of readiness for research and development (R&D) results which consist of three major levels, namely the basic research, applied research, and development levels, as illustrated in table 2.

Table 2. Indicator TRL using Tekno-Meter

9	Technology is thoroughly tested/proven through successful operation
8	Technology systems are complete and qualified through testing and demonstration in real environment/application
7	The prototype has been tested in a real environment
6	The Model or Prototype has been tested in the relevant environment
5	The technological components have been validated in the relevant environment
4	The technological components have been validated in a laboratory environment
3	Important concepts and characteristics of a technology have been demonstrated analytically and experimentally
2	The technology concept and its application have been formulated
1	The basic principles of technology have been studied

Source: BPPT (2012)

2.3 Commercial Readiness Level (CRL)

The Commercial Readiness Level (CRL) framework assesses various indicators that influence the commercial and market conditions beyond just the technology maturity. This enables key barriers to be addressed to support the commercialization of technology. Similarly, to Technology Readiness Level (TRL), CRL has a scale from 1-9 to identify the commercial readiness of the technology (Granted, 2018). TRL is often the barometer for funding bodies to assess the development stage of a product/solution, CRL can also be considered; with some funding calls explicitly stating the requirement for CRL identification. The CRL framework can also be used within a funding application to explain the forward development of a project, for example taking a product/solution from CRL 3 to CRL 6. The CRL descriptions are defined by ARPA-E shown in table 3.

Table 3. CRL Indicator

COMMERCIAL READINESS LEVELS (CRL)	
CRL 1	Knowledge of applications, use-cases, &market constraints is limited and incidental or has yet to be obtained at all.
CRL 2	A cursory familiarity with potential applications, markets, and existing competitive technologies/products exists. Market research is derived primarily from secondary sources. Product ideas based on the new technology may exist but are speculative and un-validated.
CRL 3	A more developed understanding of potential applications, technology use-cases, market requirements/constraints, and a familiarity with competitive technologies and products allows for initial consideration of the technology as a product. One or more “strawman" product hypotheses are created, and maybe iteratively refined based on data from further technology and market analysis. Commercialization analysis incorporates a stronger dependence on primary research and considers not only current market realities but also expected future requirements.

Table 3. CRL Indicator (continued)

CRL 4	A primary product hypothesis is identified and refined through additional technology-product-market analysis and discussions with potential customers and/or users. Mapping technology/product attributes against market needs highlights a clear value proposition. A basic cost-performance model is created to support the value proposition and provide initial insight into design trade-offs. Basic competitive analysis is carried out to illustrate the unique features and advantages of technology. Potential suppliers, partners, and customers are identified and mapped in an initial value-chain analysis. Any certification or regulatory requirements for products or processes are identified.
CRL 5	A deep understanding of the target application and market is achieved, and the product is defined. A comprehensive cost-performance model is created to further validate the value proposition and provide a detailed understanding of product design trade-offs. Relationships are established with potential suppliers, partners, and customers, all of whom are now engaged in providing input on market requirements and product definition. A comprehensive competitive analysis is carried out. A basic financial model is built with initial projections for near-and long-term sales, costs, revenue, margins, etc.
CRL 6	Market/customer needs and how those translate to product needs are defined and documented (e.g. in market and product requirements documents). Product design optimization is carried out considering the detailed market and product requirements, cost/performance trade-offs, manufacturing trade-offs, etc. Partnerships are formed with key stakeholders across the value chain (e.g. suppliers, partners, customers). All certification and regulatory requirements for the product are well understood and appropriate steps for compliance are underway. Financial models continue to be refined.
CRL 7	The product design is complete. Supply and customer agreements are in place, and all stakeholders are engaged in product/process qualifications. All necessary certifications and/or regulatory compliance for product and production operations are accommodated. Comprehensive financial models and projections have been built and validated for early-stage and late-stage production.
CRL 8	Customer qualifications are complete, and initial products are manufactured and sold. Commercialization readiness continues to mature to support larger-scale production and sales. Assumptions are continually and iteratively validated to accommodate market dynamics.
CRL 9	Widespread deployment is achieved.

2.4 Technology Transfer Office – background, definition, proposed to build

Supangat (2005) explains that the concept of technology transfer service offices in higher education has great potential to create new entrepreneurs through the business incubator program as a form of the Tri Darma of Higher Education in conducting research and community service. The activities of research and community service are expected to be able to turn inventions into innovations so that the value creation process occurs. Through this process, it is hoped that there will be a positive impact that will emerge, namely the commercialization of technology that can encourage the creation and improvement of social welfare (social wealth creation and social wealth improvement), which in this case is the responsibility of the technology transfer office. For universities and research institutions themselves, apart from facilitating research results for the public interest, business incubators are useful as an effort to reward, strengthen and recruit members of research faculties/institutions. Business incubator institutions that are managed by universities can answer four job needs in today's globalization era (Novel, 2001).

It is hoped that the existence of technology transfer service offices in universities can overcome the various problems mentioned by:

1. Business failure due to the absence of a potential market that absorbs the business idea being offered can be overcome through market research activities. For new entrepreneurs, this activity is useful to help analyze market opportunities and potential in the context of business creation and development, as well as a way to determine market viability and behavior in the context of supply and demand.
2. To overcome the problem of lack of managerial skills, the technology transfer service office can hold mentoring and coaching. The training is aimed at shaping and developing attitudes and behaviors of "entrepreneurs", who can be creative, innovative, and be proactive in facing environmental developments.

3. Cooperation between institutions. This program aims to create win-win solutions, the process of which takes advantage of strategic advantages for interconnected businesses to work together. The principle of mutual need will be created between organizations which ultimately results in value-added and economic benefits.
4. Establishment of business units. This program aims to direct and guide the process of conducting business/business units of an established business organization. The technical forms are mentoring, structured (periodical), and residential consultancy which is organized based on needs/requests.
5. Development. This program aims to increase capacity and develop markets for entrepreneurs and small and medium enterprises that are already established in a business. The form of development can be in the form of restructuring, engineering, product, market, and managerial.

The commercialization process of intellectual property of R & D institutions and universities indicates that there is a process or flow of institutionalized commercialization activities. Through this technology transfer service unit, commercialization of intellectual property can be facilitated by getting full assistance from the institution. This commercialization process also requires researchers to disclose research results that have the potential to be protected by intellectual property, which in turn can increase the institution's intellectual property portfolio. This portfolio is then evaluated by the team in the commercial office or technology transfer to compile a commercialization plan and allocate the necessary investment or budget. The commercialization route shows that the establishment of a new commercialized technology-based company can also be one of the commercialization targets itself in addition to the target number of licenses targeted.

The role of the technology transfer service unit in the technology transfer process is very decisive. With his experts in various fields, the technology transfer service unit can audit new technology to see its commercial prospects. When a new technology requires proof of concept activities so that the product can be more accepted by the market, the technology transfer service unit provides assistance and mentoring under the technology transfer service unit's specialization and experts within the scope of its network.

3. Methods

This research method consists of problem identification, namely how to measure the performance efficiency of a TTO in accelerating commercialization, then a literature review is carried out to find out tools in measuring performance such as goldsmith commercialization, TRL, and CRL, the next step is to carry out a framework model according to Figure 4, from In this framework, a questionnaire design and future research designs were made. Future research is conducted to test the framework that has been carried out in this study in its application to measure the performance efficiency of a TTO using the DEA method. Figure 3 shown as a method of this research.

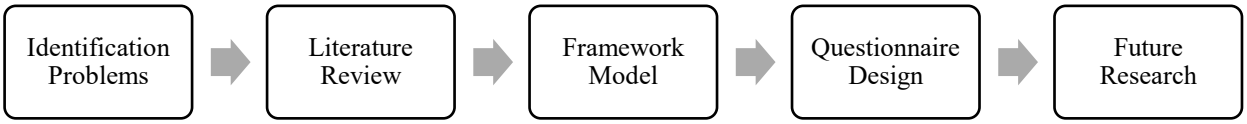

Figure 2. Method this research

4. Result and Discussion

4.1. Framework Model

After following the methods explained in section 3, the framework model has been developed as shows in Figure 4. The framework explains the model of the technology commercialization framework in the valley of death.

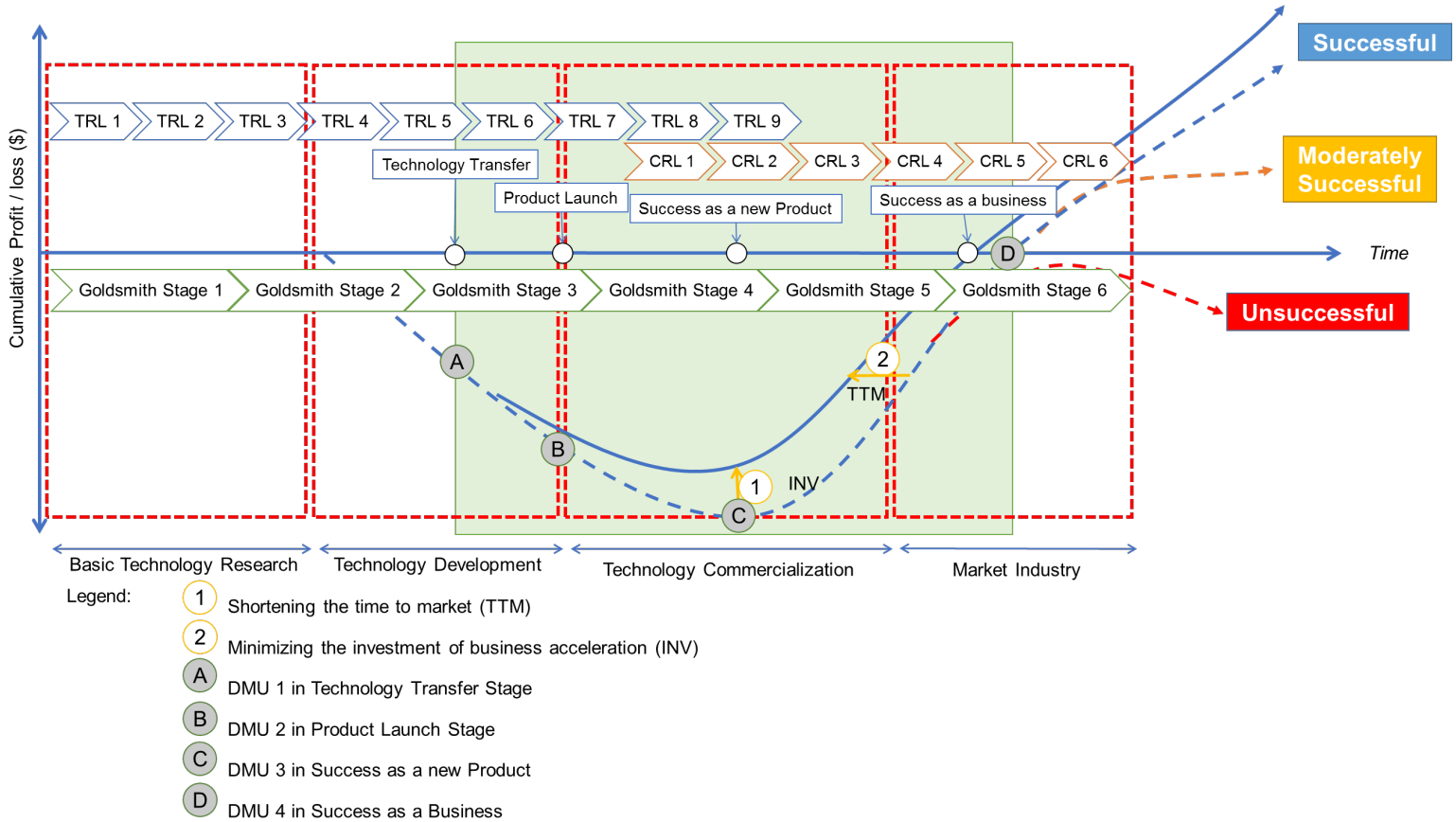

Figure 3. Valley of Death Commercialization Technology Framework Model

In this framework, there are three models to consider namely Goldsmith, TRL, and CRL. With four stages, the first is basic technology research, technology development, technology commercialization, and industrial market. The valley point of death is in the technology commercialization stage, with TRL 7, 8, and 9 as well as CRL 1, 2, 3, and Goldsmith Stage 4 and 5. In this study, the consideration of the success or failure of a TTO is considered. As shows in Figure 4, it is explained that this research area is at the technology commercialization stage starting from product launching to success as a business (if any), wherefrom this

stage there is a valley of death so the researcher wants to see what factors influence TTO in achieving success. Furthermore, this framework will become a reference in making the questionnaire.

4.2.Questionnaire Design

The questionnaire design was prepared based on a model framework that has been made, as shown in Figure 3. By combining the Goldsmith Commercialization Model and TRL concepts to measure the efficiency of the performance of a TTO. This questionnaire framework was conducted as preliminary research to determine the TTO strategy in accelerating technology commercialization. Described in Table 4 of the questionnaire design consists of 3 indicators, namely technical, market and business.

Table 4. Questionnaire Design

Indicators (Input)	Steps	Definition	Indicators	References
Technical	Business Start-Up	The business start-up step of business development is that period during which business functions (management, production, financing, legal, marketing, and human relations) are initiated by key personnel.	Equipment, processes, methods, and engineering designs have been identified, developed, and piloted	Kasie dan Belay (2013), Iqbal dkk (2013), Secundo dkk (2016), Chukhray dkk (2019)
			Process equipment and test/inspection equipment are piloted in a production environment	
			The fabrication process is generally well understood	
			The system prototype has been tested in field trials	
			Start of business activities (selling products, orders even on a small scale)	
			Establish employee recruitment criteria	
			Hires and trains core company personnel	
			Enter into contracts with buyers/orders	
			Arrange for the next stage of financing with suppliers or customers	
			The regular board of directors meeting	
			Develop a manual for business policies and procedures	
			Establish a control mechanism for cash disbursements according to the business plan	
			Create dynamic processes for strategic and tactical planning for the company	
	Production	The production step is that period during which the manufacturing process is built and full-scale production runs are implemented.	Supports commercial production	
			Has aftermarket support for the product	
			Improve the production process	
			Support warranty	
			The shape, fit, and function of the components are compatible with the operating system	
			Machines and equipment have been tested in a production environment	
			The fabrication process is piloted on a pilot scale (pilot-line or LRIP)	
			The fabrication process test shows acceptable results and productivity levels	
			System qualifies through tests and evaluations (D&E completed)	
			Ready for full-scale production (full capacity).	

Table 4. Questionnaire Design (continued)

Indicators (Input)	Steps	Definition	Indicators	References
Market	Pre-Production Prototype	The process of preparing the product for introduction into the marketplace.	Has a product production prototype	Kasie dan Belay (2013), Lockett dan Wright (2005), Markmanet.et.al,(2005b), Smilor dan Matthews (2004), Lockett dkk (2003), Iqbal et.al k (2013)
			Doing pilot production	
			Choosing an effective production process	
			Choosing economical factory equipment	
			Doing full-scale production	
			Has a commercial level design	
			Have quality control procedures	
			Produce a sufficient amount for the market	
			The operational concept has been applied	
			Technology has been tested in real conditions	
			Productivity at a stable level	
			All documentation is complete	
			Known competitor technology	
	Sales and Distribution	Definition: The sales and distribution step is that period when the product is receiving some degree of market reception by distributors and buyers.	Build product distribution and sales	
			Identify areas for market expansion	
			Assess customer satisfaction	
			Assessing distributor satisfaction	
			Improve product features	
Business	Market Validation	The process of introducing the product to the market, assessing market approaches, and obtaining customer feedback.	Doing limited product sales	Vohara dkk (2004), Cooper dan Hetherington (2003), Egeln dkk (2003), Iqbal dkk (2013), Kasie dan Belay (2013)
			Calculate sales volume, rate, and demographics	
			Design and implement customer surveys	
			Analyze customer feedback (price, design, functionality, packaging, shipping)	
			Analyze your competitors' responses	
			Incorporate marketing modifications into the market plan	
			Send design modifications to technicians	
			Validate the calculation results of the estimated production costs	
			Initial production at low Initial Production costs	
			Estimating the technology investment used	
			Estimating production prices with competitors	
	Business Growth	The business growth phase is that period during which business functions (management, production, financing, marketing, and human relations) are fully staffed and operational.	Engage in full-scale production	
			Arrange for full-scale production financing	
			Institutionalize the company's vision, mission, and policies	
			Have a process for monitoring trends and business practices	
			Identify opportunities and threats to company profits	

Table 4. Questionnaire Design (continued)

Indicators (Output)	Steps	Definition	Indicators	References
Time	Time to Market Minimize	The time needed from prototype manufacture to product acceptance in the market	The time it takes from the product launch until the product is sold	Chapple dkk (2005), Kim dkk (2008), Secundo dkk (2016)
			The time it takes from the first product is sold to the market (sold in large quantities)	
			The time needed from the time the product enters the market to large-scale production	
			The time it takes from a successful product to a successful business	
Cost	Minimize Investment Cost	Costs incurred to make a product from product launch to business success	Initial Production Costs	
			Investment costs Equipment / Asset	
			Current Production Costs (Raw Material Costs and Labor Costs)	
			Marketing and Branding Costs	
			Factory Overhead Costs (Electricity, Water, Equipment Maintenance, etc.)	

4.3. Future Research

This study aims to build a framework in performance efficiency measurement of a TTO to assess the strategy for accelerating technology commercialization so as not to fall into the valley of death. The discussion in this study explains the next research plan, collection data, process data, and analysis data. The future research plan used Data Envelopment Analysis (DEA), because The DEA model can measure the decision efficiency of a unit of activity that converts many inputs into outputs, and calculates relative efficiency. The DEA model is widely used in measuring the efficiency of performance in an environment, company, or business. The following are the stages of the next research described in Figure 4 using the DEA method.

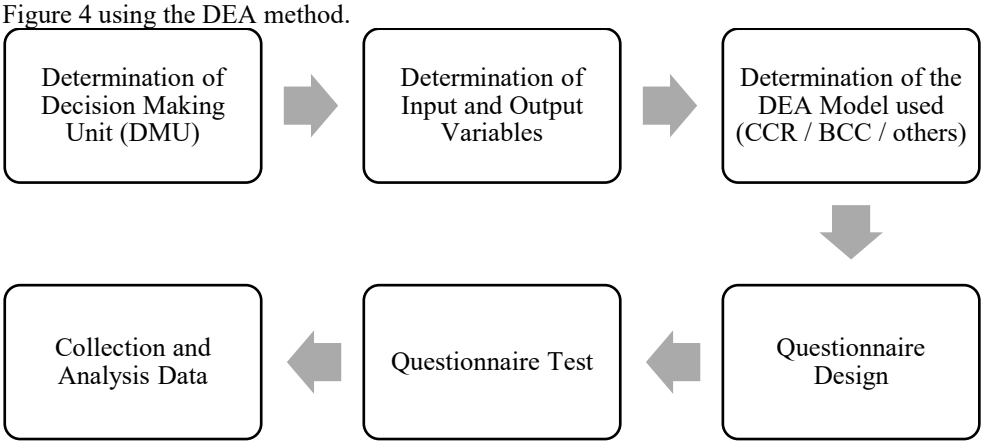

Figure 4. DEA Method to the stages of next research

5. Conclusion

The framework has been designed to develop a model for measuring the efficiency of TTO performance in universities. The model developed aims to measure the efficiency of TTO in accelerating commercialization. This model integrates the conceptual approach of Goldsmith Commercialization Technology, TRL, and CRL. From the results of the analysis of the efficiency measurement, it can provide suggestions to TTO stakeholders in Higher Education on what needs to be done to improve the efficiency of TTO performance. Further research can be carried out to test the TTO efficiency measurement framework model and can be analyzed using the DEA model. So that the final research results obtained a model for measuring performance efficiency as a recommendation to accelerate the commercialization of TTO in higher education.

References

Bhushan, B. Perspective: Science and technology policy – What is at stake and why should scientists participate? Sci. *Public Policy* 2015, 42, 887–900, 2015.

BPPT. Panduan Pengukuran Tingkat Kesiapan Teknologi: Teknometer. Jakarta: Gerbang Indah Nusantara, 2012.

Carlsson, B. and Fridh, A. Technology Transfer in United States Universities: A Survey and Statistical Analysis. Journal Evolutionary Economic, 12, 199–232, 2002.

Chirazi, J., Wanieck, K., Fayemi, P.E., Zollfrank, C., and Jacobs, S. What Do We Learn from Good Practices of Biologically Inspired Design in Innovation? Applied Science 9, 650 doi: 10.3390/app9040650, 2019.

Chukhray, N., Shakovska, N., Mrykhina, O., Bublyk, M., and Lisovska, L. Consumer aspects in assessing the suitability of technologies for the transfer. CSIT 17-20 September, 2019, Lviv, Ukraine, 2019.

Cooper S, and Hetherington L. Facilitating academic entrepreneurship: encouraging technology commercialisation through the development of entrepreneurial capability. Frontiers of entrepreneurship research. Babson College, MA, 2003.

Dalmarco, G., Dewes, M.D.F., Zawislak, P.A. and Padula, A.D. Universities Intellectual Property: Path for Innovation or Patent Competition? *Journal Technogy Management Innovation* 26, 159–170. Doi: 10.4067/s071827242011000300012, 2011.

DeVol, R., Lee, J., and Ratnatunga, M. Concept to Commercialization: The Best Universities for Technology Transfer. Milken Institute: Santa Monica, CA, USA, 2017.

Diharjo K., Sutopo, W., Sambowo K.A., Purwanto, Musyawaroh, Paryanto, Yuniaristanto, Karyanda R., Suryanto H., and Sudarisman. N. Kewirausahaan Berbasis Teknologi (Technopreneurship). UNS Press, 2014.

Egeln, J. Gottschalk, S. Rammer, C. Spielkamp, A. Spinoff-Gru ̈ndungen aus der o ̈ffentlichen Forschung in Deutschland, Baden-Baden, 2003.

Goldsmith, H.R. A Model for Technology Commercialization. MidContinent Regional Technology Transfer Centre Affilliate's Conference. Houston: NASA Johnson Space Centre, 1995.

Goldsmith, H.R. Model of Commercialization, Arkansas Small Business and Technology Development Center. http://asbdc.ualr.edu/technology/ commercialization/the model.asp, accessed date: 6 Mei 2014. 2003.

Granted. What is CRL? In posted 29th oct 2018. Accessed dated: https://grantedltd.co.uk/funding-blog/what-is-crl/. 2018.

Harlow, D. Knowledge transfer to industry at selected R1 research universities in North Carolina. Electron. J. Knowl. Manag. 2017, 15, 3–16, 2017.

Iqbal, A. M., Iqbal, S., Khan, A. S., and Senin A. A. A Novel Cost Efficient Evaluation Model for Assessing Research-Based Technology Transfer between University and Industry. *Jurnal Teknologi (Social Science)* 64:2(2013) 87–91| www.jurnalteknologi.utm.my | eISSN 2180–3722 | ISSN 0127–9696, 2013.

Kaiser, M. K., Hashemi Farzaneh, H., and Lindemann, U. Bioscrabble –The role of different types of search terms when searching for biological inspiration in biological research articles. DS 77: Proceedings of the DESIGN 2014 13th International Design Conference, 2014.

Lockett A, Wright M, and Franklin S. Technology Transfer and Universities'spin-out Strategies'. Small Bussiness Economy. 20:185–200, 2003.

Markman G, Phan. Balkin, D. and Gianiodis, P. Innovation speed: Transferring University Technology to Market. Research Policy. 34(7):1058–1075, 2005b.

Nebraska Business Development Center - NBDC. Goldsmith Technology Commercialization Model. Diakses pada Juni 2018 dari Nebraska Business Development Center. https://www.unomaha.edu/nebraska-business-development-center/technology-commercialization/goldsmith-technology/index.php, 2018.

Novel, D. Inkubator Bisnis Sebagai Salah Satu Sarana Perwujudan Misi Perguruan Tinggi, 2001.

Phan, P.H., and Siegel, D.S. The effectiveness of university technology transfer. Found. Trends Entrepreneurship. 2006; 2, 77–144, 2006.

Rogers, E.M., Yin, J., and Hoffmann, J. Assessing the effectiveness of technology transfer offices at US research universities. J. Assoc. Univ. Technol. Manag. 2000, 12, 47–80, 2000.

Secundo, G., Beer, C. D., and Passiante, G. Measuring university technology transferefficiency: a maturity level approach. Measuring Business Excellence, Vol. 20 NO. 3 2016, pp. 42-54, , ISSN 1368-3047, DOI10.1108/MBE-03-2016-0018, 2016.

Siegel, D.S., Veugelers, R., and Wright, M. Technology transfer offices and commercialization of university intellectual property: performance and policy implications. Oxf. Rev. Econ. Policy 2007, 23, 640–660, 2007.

Siegel, R.A, Hansen, S.O. and Pellas, L. H. Accelerating the Commercialization of Technology Through Co-Operation. *Industrial Management and Data System*, Vol. 95. No.1.18-26, 1995.

Smilor, W. Matthews, J. University Venturing: Technology Transfer And Commercialisation In Higher Education. *International Journal Technology Transfer Commercialization*. 3(1):111–128, 2004.

Sutopo, W. Book Review: Technopreneurship; unpublished, Surakarta, Central Java, 2015. 7, 2015.

Sutopo, W. Astuti, R.W., and Suryandari, R.T. Accelerating a Technology Commercialization; with a Discussion on the Relation between Technology Transfer Efficiency and Open Innovation. *Journal Open Innovation Technology*, Mark. Complex. 2019, 5, 95; doi:10.3390/joitmc5040, 2019.

Tunca, F. and Kanat, O. N. Harmonization and Simplification Roles of Technology Transfer Offices for Effective University – Industry Collaboration Models. 3rd World Conference on Technology, Innovation and Entrepreneurship (WOCTINE), 2019.

Vinig, T. and Lips, D. Measuring the performance of university technology transfer using meta data approach: The case of Dutch universities. Journal Technology Transfer 2015, 40, 1034–1049. doi:10.1007/s10961-014-9389-0, 2015.

Vohara, A. Wright, M., and Lockett, A. Critical Junctures In The Development Of University High-Tech Spinout Companies. Research Policy. 33:147–175, 2004.

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