Model Development for Downstream of Industrial Engineering Product Design Research: From Product Research Oriented to Product Market Oriented

Mohammad Riza Radyanto [1,a)], Firman Ardiansyah Ekoanindyo[2,b)], Antoni Yohanes[3,c)]

[1,2,3] *Industrial Engineering Department, Faculty of Industrial and Information Engineering Stikubank University, Semarang, Indonesia*

[a)]Corresponding author: rizaradyanto@edu.unisbank.ac.id
[b)]firman@edu.unisbank.ac.id
[c)]antoni@edu.unisbank.ac.id

Abstract. Most of the research results of students and lecturers in the Industrial Engineering Department Stikubank University end up in thesis reports or even better are scientific articles stored in a library and the highest level is published in accredited scientific journal. These has happened in real terms and has been proven with 63 appropriate technology-based products resulting from the results of their research for the 2008-2023 period, 95.2% were not utilized by the wider community and were even downstreamed as research results that were commercialized. This means that the products produced by these activities mostly end up in the Valley of Death. Weak downstreaming of research results and their utilization is due to the fact that the products produced prototype have Technology Readiness Level (TRL) level 3 up to 4, the weak role of the business incubator as a University Technology Transfer agent and limited funding in product development making it only research-oriented, not yet market-oriented. This study aims to generate a research downstream model of Industrial Engineering product design research using the literature review method to develop a theoretical framework model by analyzing the potential and resources currently owned, and compiling a gap analysis by comparing it with the ideal conditions that must be possessed by higher education institutions. The result of this research is the formulation of a Quadruple-Cycle Helix-based product design research downstream model, namely: Academia, Industry, Government and Community that are integrated in a sustainable cycle. The findings of this study are expected to have implications for the ongoing downstream research of higher education by changing the concept of a research-based product oriented into a sustainable market-based product oriented.

Keywords: *Valley of Death, Technology Readiness Level, Research Downstream, Quadruple-Cycle Helix*

INTRODUCTION

Product Design and Development is one of the 14 Industrial and Systems Engineering Body of Knowledge (BOK) released by the Institute of Industrial and Systems Engineers (IISE) relating to the design, improvement, and installation of people, materials, equipment, information, also energy integrated systems. Product design and development is the process of creating new goods by effectively and efficiently developing concepts. From the perspective of Industrial Engineering, the methods and analyses used to assist effective decision-making throughout development. Since its establishment in 2001 the Industrial Engineering Department at the Faculty of Information Technology and Industry, Stikubank University, in the educational curriculum there are several courses that refer to BOK namely Ergonomics-Based Design, and courses that use Ergonomics principles. These courses have learning outcomes so that students have the ability to design, develop an ergonomics-based functional product that can be used by society and the wider market. In its development, until 2023 there are as many as 63 functional tools were produced from the output of the undergraduate final project as a result of research by students and lecturers but 95.2% of these tools could not be downstream and were only research-oriented products and not yet market-oriented products and were in the "Valley of Death" phase.

There are many reasons why higher education research products have not been commercialized, including the undeveloped triple helix synergy between university-government and industry [1]. He issued the postulate that the interaction of 3 stakeholders is essential to enhancing the environment for innovation in a society based on knowledge. The Industry operates at Triple Helix as a production locus; Government as a source of legal agreements that ensure sustained communications and transactions; Universities as a source of cutting-edge information and science, and generative principles of knowledge-based economy.

Another reason for the non-commercialization of higher education research products is related to the existence of the term Valley of Death referred to in several studies, according to [2], there is a fairly widespread phenomenon, colloquially called Death Valley when technology is not adopted by the market due to the inability to advance. Through the commercialization phase and the technology demonstration phase. [3] in their research stated that scarcity of funding sources for technology projects that are no longer considered basic research but are not yet far enough to develop a business plan. Limited research funds owned by most universities, especially private universities add to the list of reasons for the failure of commercialization, although currently there are many funding schemes from the Republic of Indonesia's Ministry of Education and Culture's Directorate General of Higher Education, which have not yet reached all private universities in Indonesia.
Quoting from the US Department of Energy, [2] described that the Valley of Death has a correlation with funding which is divided into 4 stages: Personal Saving, Seed Capital, Pre-Venture Capital, and Venture Capital, as in **FIGURE 1**.

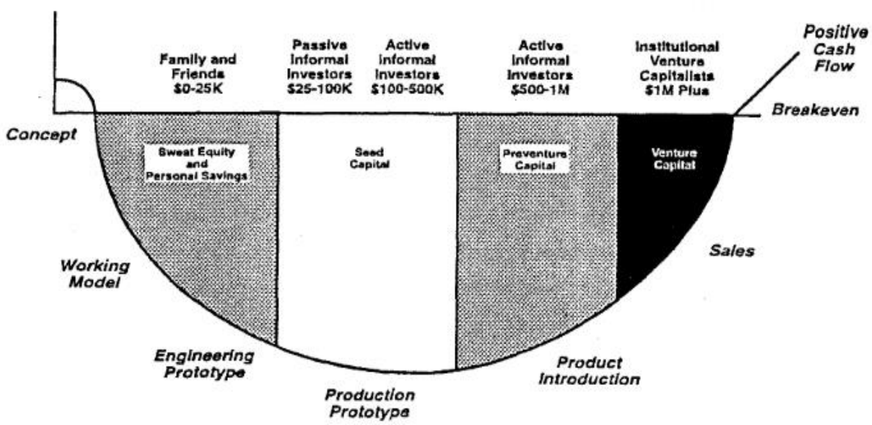

FIGURE 1. Valley of Death adapted from US Department of Energy (1991) cited from [2]

Gap analysis of this study was prepared by comparing the potential conditions and resources that are currently owned and the ideal conditions that must be owned by higher education institutions referring to the Technology Readiness Level (TRL) and the type of research that has been and will be carried out regarding the preparation of the model. Referring to the TRL, are a methodical metric or measuring system that facilitates evaluations of a specific technology's maturity and the fair comparison of maturity between various kinds of technology. So far, the research results still refer to TRL Level 3, namely key function and/or distinctive proof-of-concept in analytical and experimental research. Details can be seen in **FIGURE 2** below:

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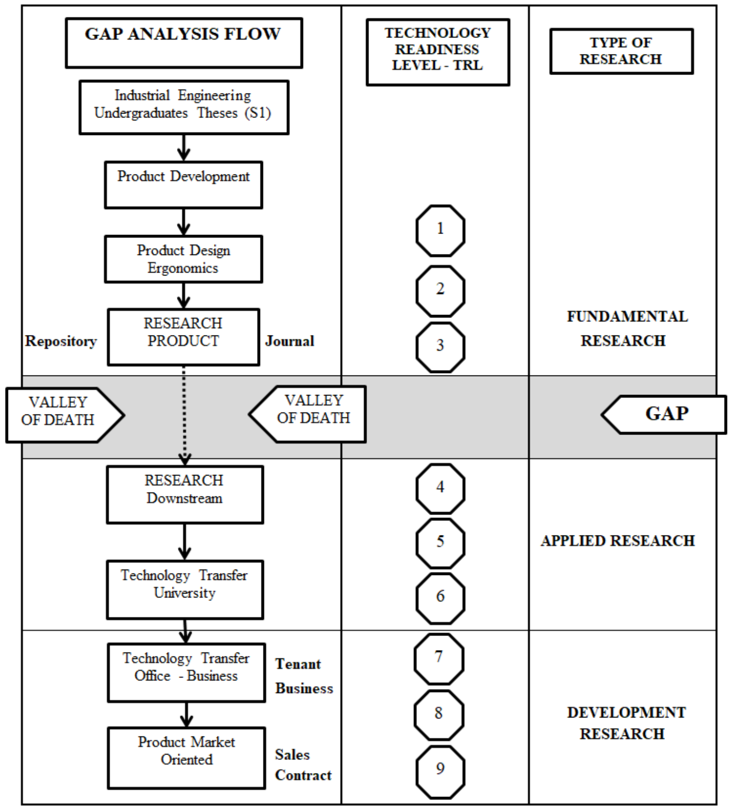

FIGURE 2. Gap Analysis of Research

METHODS

Product Design

The findings state that 95.2% of research products of industrial Engineering students and lecturers in product design are in the valley of death and need to get the best solution for the future. The product designs produced by them must be market- oriented, especially in the development of new products according to [4] new product design is highly demanded by the market because it supports the development and competitiveness of businesses. Several steps that need to be carried out in product design refer to the research of [5] which states that early on in a product's development, it is important to do to improve product sustainability performance and the need to apply the Checklist for Sustainable Product Development (CSPD) was developed in close collaboration with practitioners.

[6] conducted a literature study discussing Market Orientation Integrated with Product Development, What Makes Market Oriented Product Development? The literature on product development is mainly aimed at determining the factors that influence performance are: 1) the number of new products, 2) the existence of a product development project or 3) the product development process and 4) how market orientation affects innovation. [7] conducted research with a sample of 206 medium-sized manufacturing companies.Studies indicate that the performance of new product development is positively impacted by entrepreneurial orientation.

Success factors for specific new product development include: 1) These are tactical and capture the traits of the project for a new product or the actual product, 2) Drivers of business success include organizational and strategic elements including environment, culture, leadership, the company's innovation strategy, and how it determines whether to spend in R&D, and how the organization is structured for New Product Development, 3) The methods and practices employed by the company to manage NPD [8]

Research Downstream and Research Commercialization

Research downstream is an important factor in producing market-oriented research products [9] in his research said that organizational support has a positive impact on the process of downstream research results where researchers who combine abilities in research (upstream) will find it easier to create capabilities in commercializing research results through the creation of a business unit (downstream). Researchers say that downstream research results is similar to the act of introducing a recently made good or service to the regional, broader national, or international market is known as research commercialization.

[10] in his article states that Entrepreneurship is an Engine of Innovation. The accumulation of entrepreneurial knowledge and culture is an important resource for creating wealth from the commercialization of research resulting in scientific advancement and the development of New Technology-Based Companies (NTBC). He reviews a model created by [11] as in **FIGURE 3**.

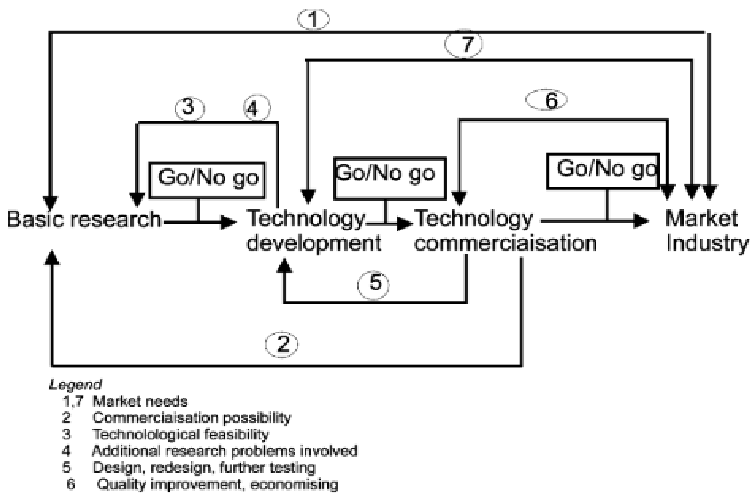

FIGURE 3. The University model of research commercialization by [11] cited from [10]

[11] correlated the results of basic research with market demand associated with the development of technology and the commercialization of technology produced by universities through the use of research results.

Technology Transfer University

Learning about technology transfer in universities we must learn from the experience of China and Korea in world technology development. [12] conducts a study that discusses how Technology Holding Companies (THC) influence university discovery to traverse the Valley of Death. THC, a unique incubation model created exclusively to market university ideas. The study verified the effect of THC on university incubation productivity. The findings indicated that in the group of universities with a high level of entrepreneurship, universities with THC were less efficient at the invention stage but more effective at the commercialization stage than universities without THC at all. This suggests that THC decreases productivity at the discovery stage by acting as a gatekeeper, but at the commercialization stage, increases productivity by acting as a sponsor. In addition, this research found that the effect of THC was more pronounced at universities with a high entrepreneurial orientation compared to universities with a low entrepreneurial orientation.

[13] conducted research which proves that China has made a historically significant investment in research during the last three years. The primary alternative for the international scientific community now is Chinese institutions. There are five topics of concern in his research: (1) Governmental action and the National Innovation System, (2) University Operated Enterprises (UOE), University Science Parks (USP), and spin-offs, (3) University Policy and Technology Transfer Offices (TTO), (4) University Industry Linkages (UIL), and (5) University Patents and Licensing. [14] researched technology transfer in China involving international companies and technology transfer policies need to consider the influencing factors from various sources and levels. Governments should make an effort to preserve the potential for true innovation and boost the effectiveness of global technology transfer.

The university as the parent institution of the Industrial Engineering Study Program must optimize the role of the business incubator in realizing Technology Transfer Universities (TTU) by synergizing research results in the form of product prototypes, collaborating with industry and supported by university policies through regulations that support them.

[15] has a collaborative perspective of knowledge and technology transfer. In his view, academia and industry can be connected directly via the Internet through collaborative organizations. Collaborative organizations serve as platforms to match partners and the resources they need to develop their products. They host, operate, and advertise their web-based organization as an alternative to conventional methods of knowledge and technology transfer. As depicted in **FIGURE 4** below:

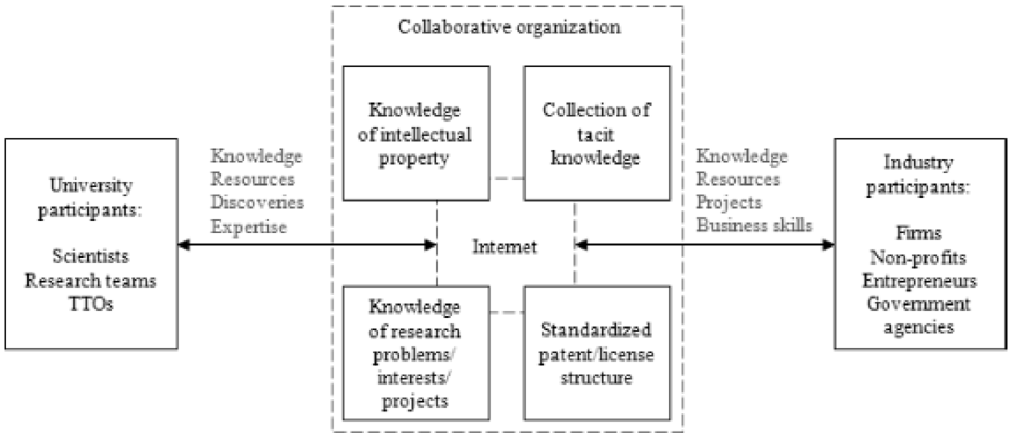

FIGURE 4. Collaboration in the transfer of knowledge and technology from universities [15]

Stikubank University already has a Technology Transfer Office (TTO) which is represented in a business incubator (SBS Business Incubator) and needs to be optimized in its management because so far its function in carrying out the process of transferring technology research results is still lacking. The lack of collaboration with industry is one of the factors for the weak technology transfer function so that a new model is needed in realizing the down streaming of research results.

RESULT AND DISCUSSION

Data Processing

The Government of the Republic of Indonesia issued a Regulation of the Minister of Research, Technology and Higher Education Number 42/2016 concerning the Measurement and Determination of Technology Readiness Level (TRL) which was designed to reduce the risk of failure in the use of technology [16]. This measurement refers to the white paper [17] where The NASA Management Instruction (NMI 7100), which addresses integrated technology planning at NASA, recently incorporates the TRL technique, which has been utilized intermittently in NASA space technology planning for many years. According to [16] TRL summary are : 1) TRL-1 : Basic principles seen and reported, 2) TRL-2: Technology concept or application formulated, 3) TRL-3: Proof of concept for an analytical and experimental critical function or feature, 4) TRL-4: Component or breadboard validation in laboratory environment, 5) TRL-5: Component or breadboard validation in relevant environment, 6) TRL-6: System, model or prototype demonstration in a suitable environment , 7) TRL-7: System prototype demonstration in actual setting, 8) TRL-8: The system is complete and reliable through testing and demonstration in a real environment and 9) TRL- 9: The system has successfully been tested via operation.

The results of research by students and lecturers in the Department of Industrial Engineering Undergraduate Stikubank University have a TRL of 3 to 5 with product application capabilities in micro, small, and medium scale (UM) to large scale companies (UB). Product application capability is a type of industrial business scale that is able to downstream products according to the capital they have. Details are shown in **TABLE 1**.

TABLE 1. TRL Research Product for Undergraduates Theses in Industrial Engineering UNISBANK

No	Year of Student	Name of Product	TRL	Applicable in
1	2007	Fertilizer Disposal Tools	4	UB

2	2007	Portable Coconut Screaming Machine	4	UM
3	2007	Cassava Chopping Machine	4	UM
4	2008	Household Scale Biogas Reactor	4	UB
5	2008	Low Rider Bicycle Seat	4	UB
6	2011	Coconut Screaming Tools	4	UM
7	2011	Hammock Sleeping Bag	3	UM
8	2011	Solving Table Chair Tools	3	UB
9	2011	Corn Seed Shrink	3	UM
10	2011	Chopper Raw Materials Banana Crips	3	UM
11	2011	Chicken Bringing Tools	4	UM
12	2011	Jenang Pressing Tool	4	UM
13	2011	Packaging Paper Press Tool	4	UM
14	2011	Tofu Cutting Tools	3	UM
15	2012	Raw Materials Chopper Of Cassava Chips	4	UM
16	2012	Aluminum Riving Machine With Pneumatic System	3	UB
17	2012	Screen Printing Table	3	UM
18	2012	Screen Printing Dryer	3	UM
19	2013	**Ice Cream Maker -Energy Saving**	**5**	**UM**
20	2013	**Semiautomatic Quill Removal Machine**	**5**	**UM**
21	2013	Red Brick Maker	3	UM
22	2013	Embossing Machine	4	UB
23	2013	Semiautomatic Chicken's Intestines Cleaning Machine	4	UM
24	2013	Semiautomatic Banana Chips Chopper Machine	4	UM
25	2013	Manual Bottle Pressing Tool	4	UM
26	2013	Jelly Cut Tools + Rack	4	UM
27	2013	Multipurpose Ladder Troly	4	UM
28	2013	Cow Trip Offal Brush Tools	4	UM
29	2014	Semiautomatic Hot Print Foil Cutting Machine	4	UB
30	2014	Toffu Cutting Machine – Develop	4	UM
31	2014	Semiautomatic Gemstone Cutting And Grinding Machine	4	UM
32	2014	Manual Corn Clubot Peeler	4	UM
33	2014	Fruit Picker Tools	4	UM
34	2015	Ring Knife And Coconut Splitting Tools	4	UM
35	2015	Mechanical Plate Roll Machine	4	UB
36	2015	Hatch Egg Machine	3	UM
37	2015	Tool Cutting Crops *Lontongan*	4	UM
38	2015	Bed Cover Packing Tools	4	UM
39	2015	Automatic Liquid Soap Making Stirring Machine	3	UM
40	2015	Styrofoam Cutting Tool	3	UM
41	2015	Ergonomic Wood Cutter	3	UM
42	2015	Electric Lighters Using Solar Panel	3	UM
43	2015	Ergonomic Table - Multifunction Folding Chair For Cafe	4	UM
44	2015	Multifunctional Creative Desk	4	UM
45	2016	Ergonomic Semiautomatic Coffee Bean Roaster	4	UM
46	2016	Ergonomic Gallon Washer	4	UM
47	2016	Semiautomatic Soap Stirring Tool	3	UM
48	2016	Automatic Shoes Drying Machine	4	UM
49	2016	Folding Clothes Ironing Table	4	UM
50	2016	Trolley For Transporting Goods	3	UM
51	2017	Automatic Shoes Drying Machine-Developing Product	4	UM
52	2018	Clothes For Kindergarten Students	3	UM
53	2018	Goat Dung Refining Tool	3	UM
54	2019	Melinjo Seed Roaster	3	UM
55	2019	Portable Lawn Mower	4	UM
56	2019	Melinjo Seed Roader Tool	3	UM
57	2019	Portable Lawn Mower Design	4	UM
58	2019	Automation Mushroom Rack With Spora Filter	4	UM
59	2019	**Parijotho Automatic Juice Extractor**	**5**	UM
60	2021	Solar Corn Sheller	4	**UM**

61	2022	Portable Cool Box	4	UM
62	2022	Semiautomatic Bottle Cap	3	UM

Of the 62 products, there are only three products that can be downstreamed are : 1) Ice Cream Maker –Energy Saving 2).Semiautomatic Quill Removal Machine and 3).Parijotho Automatic Juice Extractor with TRL-5 according to [18] and funded by the Director General of Higher Education through the 2019 Technology-Based Startup Program (PPBT 2019). What does that mean? **95.2%** of the research results of students and lecturers have not been down streamed. One of the reasons this product has not been down streamed is TRL which is still low and there is no capital to commercialize it which is summarized in **TABLE 2**

TABLE 2. Summary of The Products's TRL

TRL	Number of Product	%	Description of TRL
TRL - 3	21	33.9	Proof of concept for an analytical and experimental critical function or feature
TRL - 4	38	61.3	Validation of components and/or breadboards in a lab setting
TRL – 5	3	4.8	Validation of components and/or breadboards in relevant environments
TOTAL	**63**	**100.0**	

Model Development

Universities have a significant impact on the commercialization of university-invented technology, which is a key factor in economic growth. Technology transfer activities, which were previously carried out mainly by top universities worldwide such as Stanford University, Massachusetts Institute of Technology, and the University of California, are now carried out nationally. Transfer of technology has the potential to generate income for universities, create research links between academia and industry, also strengthen national economic development and growth [15]. [1] stated that at the beginning Triple Helix began to interact to improve the local economy then the industry will play a role in applying knowledge to form the basis of company formation, where government and industry increasingly support academic development. According to [19] University research results must be supported by policies at the higher education level.

According to our research, the Triple Helix concept still encounters many weaknesses where when the downstream process at the academy level is not supported by funding from both the industry and the government, the process will stop and will not be carried out properly. In this research, we developed a mode that involved 4 stakeholders: Academies – Business – Government, and Society. These four elements are bound in a continuous cycle that will be interrelated and sustainable and is called the Quadruple-Cycle Helix which places 1). Academia as Innovator creators of innovations from products developed, 2). Industry, as an elemental catalyst that accelerates the occurrence of 'reactions', 3) Government, as a regulator that makes regulations and policies that support the process of research downstream and 4). Community, as a connector that connects 3 helices so that it doesn't break to form a cycle because community also means the 'market' of the downstream product which is described in **FIGURE 5** below:

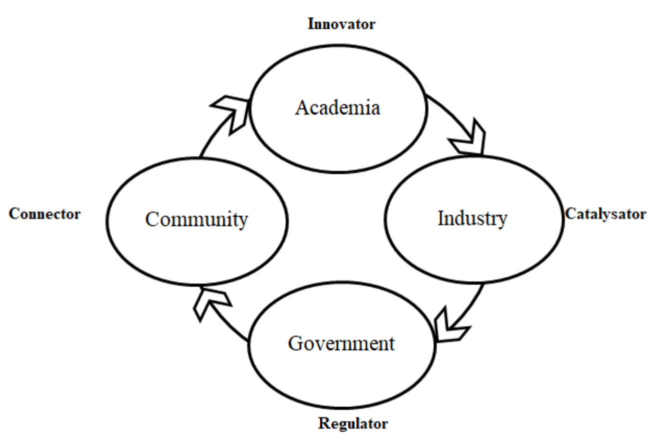

FIGURE 5. Quadruple-Cycle Helix

The Technology Transfer Office model represented by the business incubator that we already have is developed by combining four stakeholders where each has a role as shown in **FIGURE 6**.

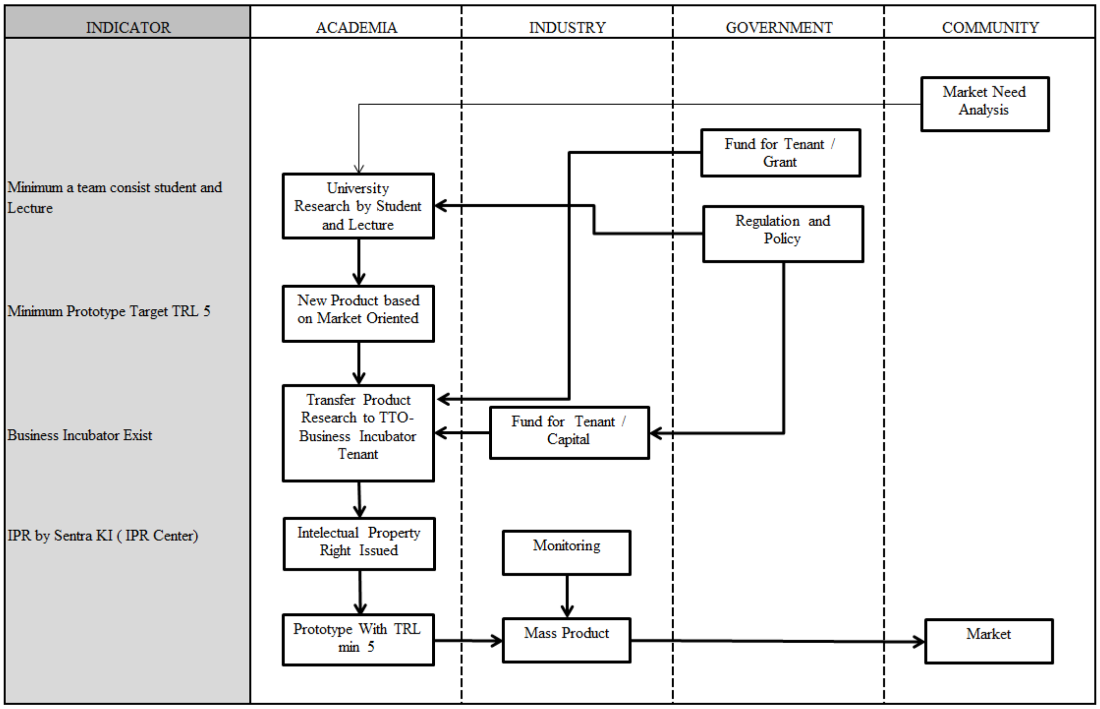

FIGURE 6. Model Development for Downstream Research

Research is prioritized by a team consisting of students and lecturers who conduct product design research to produce a new market-oriented product. The product is expected to have a minimum TRL of 5 with the ability to validate components and/or breadboards in a relevant environment and meet the requirements for entry to TTO in the form of a business incubator where there is a tenant company that is ready to commercialize the research product. It is important to arrange IPR for every research result submitted to protect its intellectual property. The role of industry begins when entering mass production, where funds for assisting capital are invested in universities other than funds in the form of grants from the government. The government's other function is to issue policies that support the implementation of downstream research. Apart from being a market for the products produced, the community also acts as a target for market needs.

CONCLUSIONS

From the model for downstream of Industrial Engineering product design research that has been designed in this study, if implemented by the Stikubank University in the future, optimal results will be obtained and solve product downstream problems which only reach the level of scientific journals. Three outcomes are expected from the model These are: 1) Increasing the TRL of Research Products, 2) Establishing Quadruple-Cycle Helix synergy involving Academia as an innovator, Industry as a catalyst, Government as Regulator, and Community as Connector in a sustainable cycle and 3) Increasing role of Business Incubators in acting as a Technology Transfer University Agent and connecting the 4 helixes. For future research, it is necessary to add performance indicators to this model by implementing a Performance Management System for Business Incubators.

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