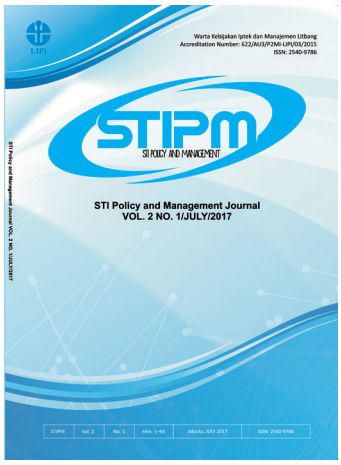

Journal of STI Policy and Management

Publication details, including instructions for authors and subscription information: http://www.stipmjournal.org/

Development of National Technology Audit Policy

Subiyanto

Center for Technology Audit, Agency for Assessment and Application of Technology

Version of record first published: 15 July 2017

To cite this article: Subiyanto. (2017). Development of National Technology Audit Policy. *Journal of STI Policy and Management,* 2(1), 53–68

To link to this article: http://dx.doi.org/10.14203/STIPM.2017.68

ISSN 2540-9786 (Print); ISSN 2502-5996 (online)

Accreditation Number: 622/AU3/P2MI-LIPI/03/2015

JOURNAL OF SCIENCE, TECHNOLOGY AND INNOVATION POLICY AND MANAGEMENT (STIPM JOURNAL), Volume 02, Number 01, July 2017

FOREWORD by EDITOR-in-CHIEF

We are very pleased to inform readers that *Journal of Science, Technology and Innovation Policy and Management* (STIPM Journal) Vol. 2, No. 1, July 2017 is now ready for public reading.

The STIPM Journal is an online research journal managed by the Center for Science and Technology Development Studies at the Indonesian Institute of Sciences (PAPPIPTEK-LIPI). As a peer-reviewed journal, the STIPM Journal provides free access to research thoughts, innovation, and original discoveries mostly aimed at scholars.

In this edition, the STIPM Journal contains six articles dealing with science, technology and innovation policy and management written by scholars from Japan, Australia, and Indonesia.

The first article is entitled "Innovation Process of Natural Resource-based Firms in Four ASEAN Economies: A SEM Approach" by Masatsugu Tsuji, Hiroki Idota, Yasushi Ueki, and Teruyuki Bunno. Using a structural equation model (SEM), this paper discusses the innovation process in natural resource-based industries in Vietnam, Indonesia, the Philippines, and Thailand in comparison to other assembling and processing industries by focusing how factors affect product as well as process innovation.

The second article is written by Noel Taylor-Moore, entitled "The Innovative Policy Options for Coastal Fisheries Economic Development: A Case of Kwandang Bay Coastal Ecosystem". This article uses a policy innovation framework in the context of STI inputs and a multi-level perspective (MLP), selects a potential site in which a fisheries economic development hub would be implemented, and performs a SWOT analysis of the selected site as a hub.

Erman Aminullah, Trina Fizzanty, Karlina Sari, Rizka Rahmaida, and Qinan M. B. Soesanto present the third article, "Interactive Learning for Upgrading and Growth: Case of Indonesian Fishery Firms." This article discusses an interactive learning model for upgrading and growth in Indonesian fishery firms using the case of fish processing and aquaculture (shrimp). The model suggests that the dynamics of upgrading and growth through interactive learning will be able to continue in a stable manner as constraints from limiting elements are eased through: combating illegal fishing; encouraging interaction with universities; shifting to higher added-value products; increasing institutional support for global trading; preventing shrimp diseases; and providing infrastructure, business facilities, and regulation information.

The fourth article, entitled "Developing the Marine and Fisheries Industry in Pangandaran using a Bioecoregion-based Technopark Framework", is written by Atikah Nurhayati and Agus H. Purnomo. This article discusses how to establish a marine and fisheries technopark in Pangandaran. By using gap and SWOT analysis, it was found that particular recommendations for improvement should be made,

the existing bioecoregional environment and development variables in Pangandaran would support the development of a marine and fisheries technopark.

The fifth article, entitled "Development of National Technology Audit Policy", is presented by Subiyanto. This article discusses the concept of a national technology auditing policy, particularly with regard to infrastructure requirements, and with emphasis on technical regulation effectiveness and implementation tool readiness. This article discusses setting a policy agenda by discussing the governance aspect of national technology auditing.

The final article is written by Anugerah Yuka Asmara and Toshio Mitsufuji with the title "Photovoltaic Development from the New Order Era to the Reform Era in Indonesia: From a Technological Innovation System Perspective". This article discusses the phenomena of PV development between the New Order era and the Reform era using a technological innovation system (TIS) approach. This paper concludes that PV projects and technology could not be developed en masse without intervention from the government in both the New Order era and the Reform era.

We also would like to thank the authors, editors, and reviewers who have worked very hard for this edition. We hope that all the articles featured in this edition proves useful to the reader.

Jakarta, 16 July 2017

Editor-in-Chief

JOURNAL OF STI POLICY AND MANAGEMENT

Volume 2, Number 1, July 2017

LIST OF CONTENTS

STI POLICY AND MANAGEMENT
Journal homepage: http://www.stipmjournal.org

Development of National Technology Audit Policy

Subiyanto
Center for Technology Audit, Agency for Assessment and Application of Technology

ARTICLE INFO

Article History:
Received : 31 August 2016
Revised : 06 July 2017
Accepted : 10 July 2017
Available online : 15 July 2017

Keywords:
Technology audit
Agenda setting
Mandatory technology audit
Technology audit tools
Technology audit objects

ABSTRACT

Indonesia's laws have stipulated technology auditing domestically, giving rise to opportunities for implementation. Nevertheless, such implementation needs more specific regulations and implementation tools. The concept of national technology auditing policy would make technology auditing a tool to ensure that technology application benefits society and technology advancement encourages national self-sufficiency. This article discusses the concept of national technology auditing policy, particularly with regard to infrastructure requirements, and with emphasis on technical regulation effectiveness and implementation tool readiness. The purpose of this paper is to raise a policy agenda setting by discussing the governance aspect in national technology auditing. The development of technology auditing policy for the national interest requires provisions for the implementation of mandatory auditing, accompanied by policy tools to develop technology auditor competence and the institutional mechanism for technology auditing. To guide technology auditor competence, this study utilizes a concept of national technology auditing policy that classifies objects of technology auditing into three categories of product technology: production technology, management of technology, and followed by related parameters used in technology performance evaluation.

I. INTRODUCTION

The development of the global economy has demonstrated the premise that economic and industry competitiveness are determined by their ability to leverage science and technology (Braun, 1998; Porter, 1998). In his *five forces* model of industrial competitiveness development, Porter (1998) includes technology as one of five components which are required for the development of industrial competitiveness. Therefore, any business entity would be hard-pressed to evaluate and improve its technology in order to maintain its competitiveness. On the other hand, development of the international trade supported with ease of information access has created ample room for international technology transfer so that the distribution and utilization of national technology in Indonesia can be rapidly developed. Ranked 41st out of 138 countries on the 2016–2017 Global

* Corresponding Author. +62 8128004373
E-mail: biyan_to2003@yahoo.com

http://dx.doi.org/10.14203/STIPM.2017.68

Competitiveness Index and 91st out of 138 on components of technology readiness (Schwab, 2016), Indonesia needs to enhance such transfer of technology for the development of its national economy. However, any enhancement should be implemented accurately, as technology application is not value-free. Technology is useful, but in certain contexts it can potentially harm the interests of other parties. Therefore, it is the duty of the government (as mandated in the constitution) to ensure that technology application in Indonesia does not harm the public and does not contradict the government's program to advance national technology for public welfare and civilization.

In summary, business entities need to evaluate and update their technology, and the government is duty-bound to ensure that technology application does not contradict the national interest. Both aims can be supported by technology audit, in which its resulting objective information can be used as the basis of decisions. Technology audit activity would support industries in increasing its competitiveness, and would also support the government in controlling the application of technology, thus benefiting all parties.

The promotion of a national technology audit to ensure public interest and advancing technology is implicitly stipulated by the state constitution. The fourth amendment to the constitution (UUD 1945), Article 28C(1), states that every citizen has the right to benefit from science and technology. This article implies a mandate to the country to protect its citizens from negative impact arising from the utilization of science and technology. Further, Article 31(5) states that the government should advance science and technology for the advancement of civilization and public welfare. Therefore, it is the government's duty to formulate relevant policy (i.e. for a favorable atmosphere) so that the utilization of national science and technology is oriented toward added value, independence, advancement, and openness, such that they become vital instruments for the development of a national, knowledge-based economy–thus, as stipulated by Article 31(5), leading to civilization advancement and better human welfare, specifically for Indonesians.

On the other hand, besides being a non value-free "asset", technology is continually developing (and so may expire), is often risky, and its ownership can be transferred and controlled (i.e. technology transfer). These natures of technology should be considered by the government when building national technology management policy so that it can be effectively utilized as per the constitutional mandate. In other words, the government should be able to intervene when necessary. One form of such intervention is the establishment of a national technology audit mechanism that can be used as a tool of development and control for technology utilization.

The purpose of this paper is to raise a policy agenda setting through discussing the governance concept of a national technology audit that is able to support industry and government, so that technology application can provide an optimum added value to Indonesia. This paper is organized into three main sections. The first reviews the literature on the concept of the technology audit and discusses the analytical approach of the study, along with the underlying theory. The second section outlines the existing policy, practices, and issues involved in the state's policy of technology audit. The third section discusses policy strengthening for the national technology audit system with emphasis on regulation, implementation tools, and concept of technology audit object. The paper ends discussion with appeals to success the national technology audit policy.

II. LITERATURE REVIEW AND ANALYTICAL APPROACH

A. Understanding of Technology Audit

Martino (1994, p. 1241) describes that technology audit is intended to evaluate the state of the organization's technology resources. These can be classified as base technologies, possessed by every firm in the industry; key technologies, those which provide the firm with a competitive edge; and pacing technologies, those needed to provide a competitive edge in the future. According to Martino, technology should be able to reveal critical issues relating to technology in the company, and for that technology taxonomy

is classified into four aspects, i.e. technical discipline, function performed, product category, and underlying science.

Meanwhile, Garcia-Arreola (in Khalil, 2000) developed a technology audit model whose purpose is for: i) determining the current status of the company; ii) identifying areas with chances of development; and iii) utilizing the best advantages of the organization's capability. Garcia-Arreola's technology audit model consists of three levels, where the second level and third level are the elaboration of its upper level. The first level consists of six categories, the second level consists of 20 studies, and third level consists of 43 elements of studies. The first level's six categories are: i) technology environment; ii) technology categorization; iii) market and competitor; iv) innovation process; v) added value function; vi) acquisition and exploitation of technology.

Chiesa, Coughlan and Voss (1996) developed a technology audit model to evaluate the innovative capability of a company through a process audit approach and performance audit. Process audit emphasizes the individual object as an innovation performer, while performance audit emphasizes the individual effectiveness of processes related to innovation. Such processes are further divided into subprocess and element. The subprocess that forms the innovation concept is further classified into the following concepts: generation process, product development, production process, technology acquisition, leadership, resource provision, and system and tool process. In the implementation of performance audit, each subprocess performance is measured against the result of innovation.

Leonard (1998) defined technology audit as a tool to evaluate and identify strengths and weaknesses of the technology capability of a company. Similar to Leonard, Kelessidis (2000, p. 2) defined technology audit as *"*a method of identifying the strong and weak points through the characterization and general assessment of the firm's basic know-how (marketing, management, finance, human, resources, etc.)*"*. Kelessidis emphasized the use of technology audits to evaluate technology capacity in small and medium sized industries or organizations, and suggested that a technology audit is performed by an external consultant in cooperation with company management and personnel. Technology audit activity covers data collection, analysis, synthesis, and audit result report.

Khalil (2000, p. 265) described the technology audit as an analysis to identify the strengths and weaknesses of an organization's technology asset, and with the purpose of assessing the state of the organization's technology against those of competitors and what is considered state-of-the-art. It is further explained that the scope of the assessment of technology covers the whole value-added function of an organization, including product technology, production technology, service technology, and marketing technology. In his book, *Management of Technology*, Khalil (2000) identified technology audits as an internal activity that is implemented by an organization to obtain a basis for plan formulation and technology strategy. In turn, a technology strategy shall become a part of the company strategy as a whole. According to Porter (1998), good relevance between the manufacturing strategy and process is key to building a competitive advantage.

Meanwhile, Shirazi (2009) described the technology audit as an imperative to measure the health of technology and welfare of an industry. Khalil (2000) explained that technology audit is a continuous process of assessment. Moreover, Khalil (2000, p. 265) reported Ford's concept of technology audit (Ford, 1988) that technology audit results should answer the following questions:

1) What are the technologies and know-how upon which the business depends?
2) How is the company's technology positioned, compared to its competitor? Is the company a leader, a follower, or a laggard?
3) What is the current position of company's technology compared to the life cycle stages of technology?
4) Where is the company's strength? Is it in the product or production technologies, or a combination of technologies?
5) Is the company effectively protecting its distinctive core technologies?

6) What emerging or developing technologies, inside or outside the company, could affect its technological position?
7) What is the value of the company's technology to its customer? Is there a big gap that gives the company an advantage in knowledge as well as in pricing its product?
8) Does the company have a systematic procedure and a supporting organizational structure that allows optimal exploitation of its technology internally and externally?
9) Does the company have technological assets that can be shared with other companies? This includes selling technology that is no longer of use to the company, creating joint ventures to exploit the company's areas of strength, and transferring technology to another company or country.
10) What emerging and developing of technologies, both inside and outside of the company, could influence customers and affect the company's market position?
11) What social, political, and environmental factors might impede the natural progress of the company's technological plans?

The knowledge and practice of auditing have been maturely developed in financial management. Mulyadi (2002) summarized the methodological concept of (financial) auditing in Indonesia by extracting expert opinion regarding understanding of the concept of (financial) auditing, and described the results as follows:

1) A systematic process which is implemented in steps or is planned; a logical, structured, organized, and aimed procedure
2) An intention to obtain objective evidence underlying statements made by individuals or business entities, without 'taking sides' or being prejudiced on such evidence.
3) Evidence collection in relation to statements made, and evaluation on the result of evidence collection intended to establish the conformity of such statements using specified criteria, quantitatively or qualitatively.
4) Such criteria or standards used as the basis to assess such statements can include:
   a. regulations stipulated by a legislative body;
   b. budgets or achievement measures stipulated by management;
   c. general principles of accounting in Indonesia.

Based on such literature study, technology audit models can be characterized as: i) done on company level; ii) by internal or external auditor; iii) with a variety of purposes and scope; iv) guided to appraise the company's technology status (strength and weaknesses); v) targeted to obtain a comprehensive and objective information base; and vi) used for preparing plans and seizing opportunities for development in order to strengthen the company's business competitiveness. Furthermore, the implementation of the concept of technology audit can adopt financial audit methodology, which is a planned and systematic process, through which objective evidence is collected with the intention to establish conformity in such evidence using specified criteria or standards (quantitatively or qualitatively), where the criteria or standard can be government regulation, management-stipulated achievement measures, or industry best practice in technology governance.

B. Technology in Context

With the understanding that technology is an implementation of knowledge, Narayanan (2001) explains technology as three levels of knowledge, i.e. tacit, codified and verified, physically presented as product, service and/or procedure. In line with Narayanan, Nataatmadja (2015) asserts that based on the relation of knowledge and best practice of technology application, technology could be present in intangible as tacit knowledge in human (human-embedded technology), tangible as an explicit knowledge on machines and tools (object-embedded technology), and is also information contained by systems and organizations (document-embedded technology). Meanwhile, from across-cultural perspective, Castells (2004) gives a picture of technology as a collection of tools, regulations, and also procedure that is an implementation of scientific knowledge on a specific work in a

possible repetitive condition. Moreover, from the linking technology and business strategy point of view, Abetti (1989) elaborates understanding of technology and depicts technology as a body of knowledge, tools and techniques, derived from science and practical experience, that are used in the development, design, production, and application of products, processes, system, and services.Khalil (2000, p. xix) states that technology has always been closely connected with society's progress and it has been linked to improvements in standards of living. The human aspiration for a better life increasingly depends upon technology and its effects on all aspects of life. Today's pace and scope of technological change are having profound effects on every human institution. Technology has enabled humans to achieve unprecedented change in their way of life.

Based on his study on major companies in different production sectors (energy, nanotechnology, biotechnology, information technology, electronics, robotics, and aerospace), Štrukelj and Dolinšek (2010, p. 575) shows that technology refers to: i) methods, techniques, procedures, processes, activities of production; ii) tools, devices, machines, apparatuses, equipment, accessories by means of which processes of production are carried out; and iii) devices (systems) and their processes that are included as components in applications as final products. In this conceptualization of technology, production refers to acquiring and distributing (delivering) energy and materials, as well as manufacturing, storing and distributing (delivering) material goods and providing services.

Based on Law No. 18 of 2002 on the National System of Research, Development and Science and Technology Implementation, technology is defined as "[a] way, method, process, tool or product produced by the implementation and utilization of science and technology that results in an added value for the fulfillment of needs for, continuity of, and enhancement of human life quality".

Ford (1988) and Braun (1998) classify technology into two general categories, i.e. product and production technology. Product technology relates to design and marketed substances, while production technology is related to the production process and/or system to produce output (a product) which meets a certain quality and makes profit. A production technology system not only uses product technology; a control function is used as well, and other technical management functions are also required to create the target product. Therefore, product technologies can be part of the production technology for other parties. For example, machine tools produced by a production tool company will be used by other manufacturing companies to produce cars, trains, etc.

The definition of technology used by Braun (1998) includes hardware and any related software in its scope. Additionally, according to Sharif (1989), the technology element can be classified as hardware, orgaware, inforware, or humanware. Nataatmadja (2015) proposes viewing hardware as technoware to emphasize that the involved element may not always be a tool, but may include any process technology that is directly involved in the production activity.

To ensure that the benefit of technology is adequately leveraged to become a vital instrument for business competitiveness and the development of a national knowledge-based economy, technology should be managed accordingly and professionally. Technology strategy is therefore an important issue. According to Braun (1998), technology strategy arises from demand for better performance illustrated using a long-term perspective. Braun divided technology strategy into three elements, i.e. technology acquisition, technology exploitation, and technology management.

To handle new technology and the global competition era, Drucker (1985) states that there is a need for entrepreneurial management, i.e. management that is able to integrate company resources such as capital, intellectual (humanware), hardware, software, and inforware to build and develop new businesses and competitiveness. Nataatmadja (2015) defines entrepreneurial management as a management that can create synergy between various parties in order to accelerate added value through a successful technology

commercialization stage or encourage the invention of new products or processes or services that are more appropriate to consumer demand.

From the above descriptions, it can be understood that there is no standard definition or scope on what technology is. As long as humans find new ideas, development of technology will likely never stop. Braun (1995) asserts that development of technology has usually skewed toward capability enhancement (faster, more compact, bigger capacity, more easily operated, more efficient, etc.). Certain technology is designed headed for convenience of human activity, particularly to substitute human-operated roles with machines (e.g. washing machine). In a technology development context, innovation systems become important, and thus technology management that induces leadership in and the mastering of technology becomes a requirement for a technology-based business organization.

C. Overseas Implementation of Technology Auditing

By 1992, researchers began to identify the need to introduce formally the discipline of technology management, including technology auditing, in college curriculums. This was intended to increase awareness in young scientists and engineers to develop innovation and technology scheme process in a more conceptual way. The emerging concept is expected to use the quantitative and qualitative approach, and not only in form of case studies or theoretically.

At the end of 2004, Anderson published a collection of teaching materials titled *Technology Audit Survivor's Guide*, which received appreciation from the National Center of Technology Planning USA; it went on to become part of science and technology curriculums. In his book, Anderson asserts that technology auditing is a positive pilot in effective technology plans.

> "It doesn't take us observers very long to realize that technology auditing, as a growing national activity, needs to have some of the "shaping" performed in a fashion similar to the way technologies planning was shaped during the late 1990's and into the 21st Century" (Anderson, 2004).

The University of Oxford, UK, executed a technology audit to evaluate commercialization and technology transfer of results from college innovation, as funded by the government budget and other sources through technology incubation program. The evaluation was focused on development output in the period of 1998–2003 and its benefit for public and business development (Cook, 2005).

Miao and Jun (2000) assessed technology used in technology capability growth and planning in specific areas in China, using the SWOT methodology. A technology audit to evaluate the capability of technology innovation in China was also performed by Yam, Guan, Pun, and Tang (2004) on 213 companies in Beijing. The focus of the study was the correlation between technology innovation capability and innovation rate, sales growth, and product competitiveness amongst the surveyed companies. The method used was a capability audit and performance audit approach. The result showed that capability of R&D and resource allocation are two significant components in determining innovation rate and product competitiveness in large and medium sized companies, while resource allocation capability determines sales growth in small companies.

Daim (1997) also conducted an evaluation of technology, specifically of the effectiveness of advanced manufacturing technologies (AMT) on organization success. Besides the technological aspect, Daim also accounted for economic, social, and political factors in his methodology and related it to strategic and tactical aspects in the technological achievements, organization function, and market condition. The evaluation model used by Daim was similar to the technology audit model developed by Garcia-Arreola (1996).

Dolinšek, Janeš, Ćosić, & Ekinović (2007) performed an assessment of model applicability for technology audits on manufacturing and service companies in Slovenia using a quantitative approach by incorporating a Likert scale scoring format (1–5), based on data obtained through a survey containing 20 areas of assessment. A score of 5 denotes the best performance, and 1 denotes the worst. The result demonstrates program innovation, acquisition, and the technology

exploitation process. Dolinšek, et al. concludes that the developed technology audit model was essentially generic, as it can be applied to various companies in the manufacturing or service sectors.

Shirazi (2009) also tested a technology auditing model on 30 publicly listed manufacturing companies in Rawalpindi, Pakistan. The purpose was to test the effectiveness of such a model as a potential instrument for Pakistan's Ministry of Industry to evaluate technology on certain industries. The audit model referred to is the previously mentioned Garcia-Arreola model consisting of 3 levels and 43 assessment elements. Test results concluded that the technology audit model can be used by the Pakistani government as an evaluation instrument for industrial technology.

Fraunhofer (2005), in Germany, also developed a rating technology model, through what was basically a technology audit as well. The model was intended to be evaluation instrument for capitalization of technology assets, including intangible assets, such as knowledge and networks. The model was applied to small and medium industry (SMI) in Europe, and was intended to create an SMI rating system that can be used by government bodies to formulate an assistance policy.

D. Framework and Underlying Theory for Developing a National Technology Auditing Policy

Tjokroamidjojo and Mustopadidjaja (1998) claim that the public policy system should cover the elements of input, process, output, and impact. Meanwhile, Law No. 12 of 2011 on procedures for preparing regulation and legislation dictates that academic papers intended for reasoning and arguing construction of law must also study the philosophical, judicial, and sociological aspects. This paper combines the above two references into an examination of national technology audit policy development, and philosophically incorporates Indonesia's 1945 Constitution (*Undang-Undang Dasar 1945*) as the input element of the policy system. The element of process is comprised of judicial and sociological issues, and the output should be proposed policy issues in support of national technology auditing. The element of impact is expected benefits from the implementation of national technology auditing policy in the future, such as increased national technology readiness. However, any impact would come after the national audit technology policy, which is an expected outcome of the study, is officially formulated and nationally implemented. Of course, the outcome and impact are agendas beyond this study. The mindset of policy development for this study is summarized in Fig. 1.

For the philosophical aspect of the policy input, this study reviews the constitution's mandate with regard to national technology auditing, whereas for the process of the policy system, it reviews the effectiveness of existing laws and other policies (judicial aspect) in accordance to sociological issues (public and industrial needs), while accounting for the nature of technology.

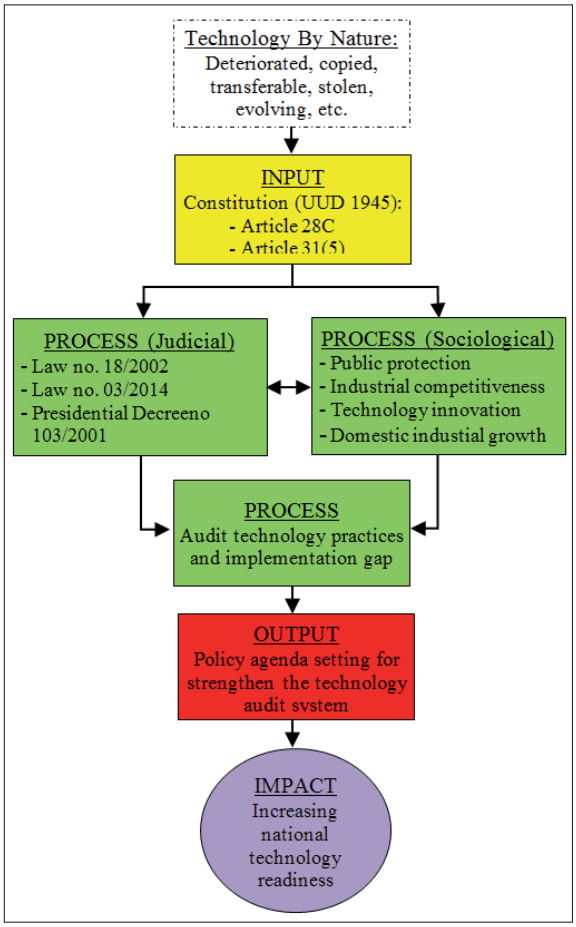

Figure 1. Framework of the study

Finally, for the output, this study examines the implementation gap (insufficiency policy) and proposes policy issues to strengthen the national technology auditing system. The proposed policy issues are expected to include the policy agenda setting for the government of Indonesia. Furthermore, referring to policy content as described by Putera (2012), this study shall identify content in technology audit policy that is considered relevant to constitutional and legislated mandate, which are required by the public and the government in order to establish technology guidelines for public welfare and national self-sufficiency.

Agenda-setting is guided by public awareness and concerned regarding salient issues, especially as communicated by the news media. Agenda-setting theory reported by McCombs & Reynolds (2002) describes the ability of the news media to influence the salience of topics on the public agenda. That is, if a news item is covered frequently and prominently, the audience will regard the issue as more important. Kozel et. al (2006, p. 33) reported three types of agenda setting as proposed by Rogers and Dearing (1998). The first is media agenda-setting. Its main focus is the priority of an issue on the mass media news agenda. The second, public agenda-setting concentrates on the ordering of one issue in relation to other issues, or the order of a set of issues on the public agenda. The third, policy agenda-setting, studies how policy actions surrounding an issue function as a response to both media and the public agenda.

Beginning from the observation that the process of agenda-setting involves discussion, debate, and persuasion among policy makers, Baumgartner and Jones (1991) developed models of agenda-setting which focused on the significance of policy subsystems. That is, the two key actors in agenda-setting are governments and the public and the relationship set out between them is one in which the government responded to public concern (Baumgartner & Jones, 1991; p.1046).The key element in the process of agenda-setting, in this view, revolves around the ability of state and societal actors to control the interpretation of a problem and thus the manner in which it is conceived and discussed (Howlett & Ramesh, 1995).

It is expected that policy agenda setting results in explicit public policy. According to Hall (2011), the basic concept of public policy is about governance. However, Hall points out that there is no single accepted definition of governance. This is reflected in Kooiman's (2003, p. 4) concept of governance as "the totality of theoretical conceptions on governing". Definitions tend to suggest recognition of a change in political practices involving, amongst other things, increasing globalization, the rise of networks that cross the public-private divide, the marketisation of the state and increasing institutional fragmentation (Kjaer, 2004; Pierre & Peters, 2000, 2005). Nevertheless, two broad meanings of governance can be recognized (see Fig. 2).

The first definition is used to describe contemporary state adaptation to its economic and political environment with respect to how it operates. Yee (2004, p. 487) provided a very basic definition of this approach by describing new modes of governance as "new governing activities that do not occur solely through governments". Furthermore, Hall (2011) describes the second broad meaning of governance is that it is used to denote a conceptual and theoretical representation of the role of the state in the coordination of socio-economic systems. However, it should be noted that the two approaches are not mutually exclusive as the use of the term "governance" as a form of shorthand for new forms of governance in Western societies is itself predicated on particular conceptions of what the role of the state should be in contemporary society and of the desirability and nature of state intervention. This second meaning can, in turn, be divided into two further categories (Peters, 2000). The first focuses on state capacity to "steer" the socio-economic system and therefore the relationships between the state and other policy actors (Pierre & Peters, 2000). The second focuses on coordination and self-government, especially with respect to network relationships and public-private partnerships (Rhodes, 1997). This second meaning of governance is thus a suitable approach for developing national technology auditing policy, especially with regard to how the government should intervene in the national system such that

technology auditing in the national interest can be implemented effectively.

III. EXISTING POLICY AND PRACTICES OF THE NATIONAL TECHNOLOGY AUDIT

Technology in general is designed for increasing quality of human life. People use technology as a tool to work better. The power of technology means that it creates economic value to the country such that the more civilized the people and the more developed the country, the more they become dependent on technology. Thus, technology benefits both people and country, but at the same time, uncontrolled use of technology could be a threat to human civilization and/or even to a country. By nature, technology is not value-free, and among other risks it contains, it is continually developing, easy to lose, or can be stolen. Moreover, technology as a capital can be invented, bought, sold or become outdated (Nataatmadja, 2015).

Considering these attributes that come with technology, the fourth amendment to the constitution of the Republic of Indonesia (UUD 1945) contains two articles referring to science and technology. The first article, Article 28C(1), stipulates that every citizen has the right to benefit from science and technology. The second article, Article 31(5), stipulates that the government is to advance science and technology for better civilization and public welfare. The first article implies a mandate to the country to protect its citizens from any negative impact from utilization of science and technology, and the second article demonstrates a mandate to the government to build and conduct programs for science and technology development and innovation such that they become vital instruments for the development of a national, knowledge-based economy, which can lead to civilization advancement and the human welfare, specifically for Indonesians.

To date, there are two laws that explicitly regulate technology auditing. The first is Article

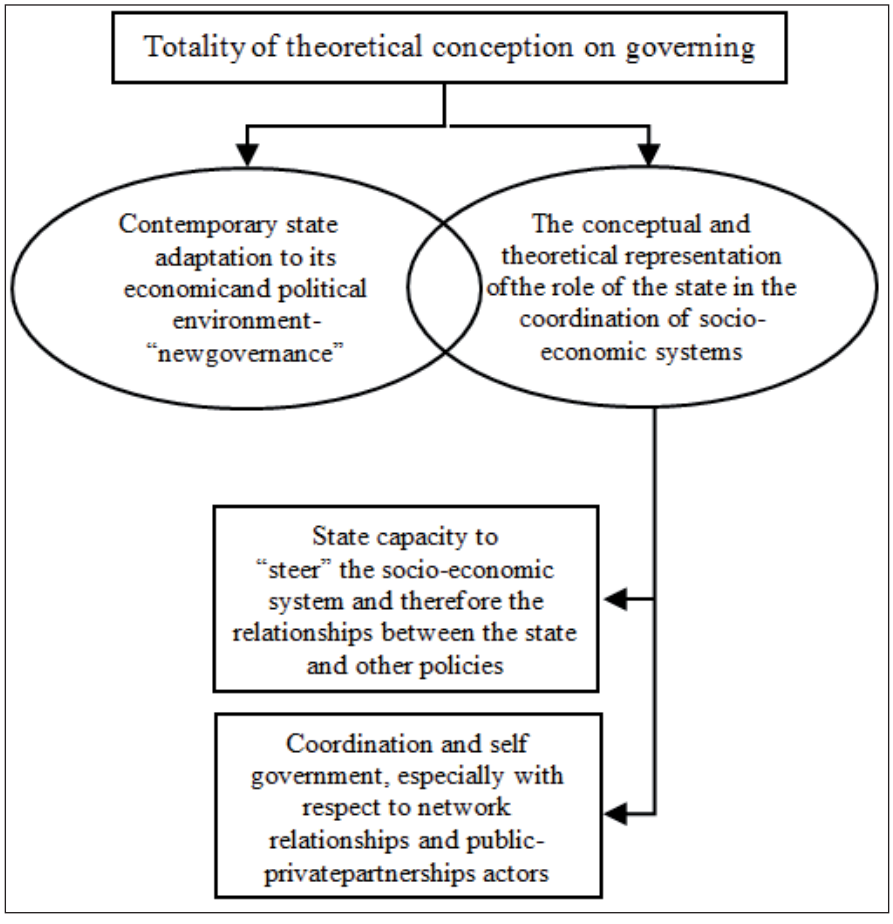

Figure 2. Definitions of Governance (Hall, 2011)

19(3)C of Law No. 18 of 2002 on the National System of Research, Development and Science and Technology Implementation, which stipulates that the government give attention to the importance of strengthening technology auditing ability to filter imported technology and protect domestic consumers and industry. So far, this regulation has not been effective, since there are no technical guidelines for implementation. Moreover, this legal mandate is limited to imported technology. Moreover, imported technology in the form of foreign investment is beholden to a different regulation which is yet to be harmonized with Article 19(3)C of Law No. 18 of 2002. The second is Article 41 of Law No. 3 of 2004 on Industry, which stipulates that in order to control the technology utilization, the government shall conduct industrial technology audits. Even though this article is a Ministry Regulation delegating technical implementation, but as recently as the end of 2016, formulation of the Ministry Regulation has not been finished yet. Therefore, Article 41 of Law No. 3 of 2004 has not been effective. Therefore, current regulations are not yet effective in obliging industry as a technology user, let alone in conducting technology audits. In practice, such regulation has only been used as reference by the government to generate activity programs regarding technology auditing. In fact, the implementation of technology audit to the industry is still a voluntary action, or at least an appeal. This shows that the government has no legal instrument for enforcing technology auditing, which means that the government has no capacity for controlling technology, especially with regard to private companies.

On the other hand, the Agency for the Assessment and Application of Technology or *Badan Pengkajian dan Penerapan Teknologi* (BPPT) has conducted several technology audits based on authority given by the Presidential Decree No. 103 of 2001. This Presidential Decree stipulates that the government gives BPPT the authority to conduct technology audits and to give technology recommendations. In practice, BPPT conducts technology audits mainly by request, particularly from high-level executives (say, the Presidential Institution or a ministry) or legislative entities (Parliamentary forum). Unfortunately, the requests are very limited in scope compared to national technology problems. BPPT cannot proactively 'force' technology audits on the private sector. In other words, BPPT cannot conduct a technology audit without the auditee's consent. Some technology audits that have been conducted by the BPPT are as follows:

1) Technology Audit (TA) on Manufacture on PT Texmaco Perkasa Engineering (TPE)

The TA on PT TPE was conducted in 2003 as per the instruction of the government (*Kabinet*). At the time, PT TPE's technology asset was under government guarantee. The objective of the technology audit was to evaluate the performance level of existing technology facilities and the resulted recommendation was used by government for consideration in policy setting for best utilization of PT TPE's technology asset.

2) Process TA on PT Toba Pulp Lestari (TPL)

The TA on PT TPL in North Sumatra was conducted in 2004 as a follow-up action on a hearing session between the government (represented by Ministry of Research and Technology) and the House of Representatives (DPR) in relation to public complaints regarding environmental issues. The objective of the technology audit was to evaluate PT TPL production technology with respect to the cleanliness of their production system.

3) Energy TA on PT PLN

The TA on the state-owned electrical company, or *Perusahaan Listrik Negara* (PT PLN), conducted in 2010, was initiated by BPPT and welcomed by PT PLN. The technology audit initiative was spurred on by the explosion of a powerhouse in Cawang, East Jakarta that resulted in a power outage in parts of Jakarta. The objective of the technology audit was to investigate the cause of the explosion, followed with future risk control recommendations.

4) TA on PTPN

The TA on the state-owned sugar sompany, PTPN, was conducted in 2011 and 2012 based on a request from the Ministry of Industry in relation to the implementation of a revitalization of the national sugar industry. The objective of the technology audit was to evaluate the performance

status of current machines and equipment to ensure the suitability of the revitalization program on machines and equipment, using government facilities.

5) TA Transportation on PT INKA and PT KAI

The TA on Kereta Api Indonesia PT KAI was conducted in 2009 under a BPPT initiative, welcomed by PT KAI. The intention was to evaluate the status of the implementation of train maintenance, to ensure the safety of trains as a public facility for transportation. Meanwhile, the TA on train manufacturing company PT INKA (Industri Kereta Api) was conducted 2011–2012 by the request of PT INKA, in relation to a production facility development plan for the acceleration of wagon production increase.

6) TA Information System on Regional Government

The TA Information System on Regional Government was conducted in the period of 2012–2014 under a BPPT initiative that was welcomed by several regional government offices. The intention was to evaluate infrastructure readiness for implementation of an information system geared toward better public services.

7) TA on Polder Development Project (Construction) and Production of Bird Flu Vaccines

This TA was conducted in 2013 by the request of the Police Criminal Detective Agency (*Bareskrim Polri*) in relation to project abuse. The TA was applied to two projects: the Kampung Bandan-Jakarta Polder project and the bird flu vaccine production project. The intention of the technology audit was to investigate fraud regarding product technology specifications, for calculating financial state losses.

Technology audit as a formal concept in Indonesia is not relatively well-known to industry or to the public. Up to the end of 2010, some parties, especially in industry, even had a misleading understanding of technology audit, because the term 'audit' is perceived as a guilty-finding exercise, as may be the case in a financial audit. The continuing socialization of the concept of technology auditing and its benefits as shown by the BPPT have gradually led to the acceptance by the public and other government bodies. Considering the benefit of the technology audit paradigm for industry and added value in society, this progress indicates that technology auditing as a public policy paradigm has been discussed nationally, involving increasing participants from government officials and industry. Several ministries have given positive responses and have started to initiate technology audit activities. Among these are the Ministry of Industry, the Ministry of Defense, and the Ministry of Energy and Mineral Resources. An example of a technology audit is one conducted by the Ministry of Industry on PT Inalum, North Sumatra. The technology audit was conducted to decide the continuity of a cooperation period in 2014. The intention of the audit was to evaluate the asset status and management of PT Inalum's technology, the results of which were used by the government to decide whether cooperation on the management of PT Inalum between the Indonesian government and a Japanese company consortium should be terminated or continued.

Experience on the implementation of technology auditing, domestically or overseas as described above, proved that technology auditing can be used to fulfill organization goals (industry competitiveness), or by the government as a tool to support its duty in providing protection to society, enforcing the law against technology abuse, empowering and advancing technology for industry, as well as protecting the country's assets. Among the implementation of the concept of technology auditing is the BPPT's identification of potential risks in technology application, and its subsequent use of the factual information gathered to compose recommendations. On the other hand, technology audits was also applied to investigate failures in technology application. Therefore, the BPPT has formulated a concept of technology auditing for the purpose of technology positioning, compliance, improvement, planning, prevention, and investigation.

So far, the only institution that has authority to conduct technology audits is the BPPT. However, the BPPT has given technology assistance to some industries and also plays a role as a technology provider, such that its independence as a technology auditor can be questionable.

This demonstrates that there should be other institutions that are competent enough to conduct technology audits. The system of national technology auditing, therefore, should put this into consideration. This would be the government's task, particularly the Ministry for Research, Technology and High Education, to build a suitable policy to optimize roles in national technology auditing for government bodies.

IV. STRENGTHENING POLICY FOR NATIONAL TECHNOLOGY AUDITING

A. Regulation Requirements

Considering the constitution, particularly Article 28C(1) that stipulates that every citizen has the right to benefit from science and technology, and Article 31(5) which states that the government is to develop science and technology for the advancement of civilization and human welfare, the government then must reinforce that technology cannot be utilized solely for individual or business interest. These constitutional mandates contain the message that there is a national responsibility for every technology user in Indonesia. The first message, that technology utilization shall not undermine the public, should be directed to industry. The second message, that regulations regarding technology utilization and implementation shall aim at technology enhancement for the purpose of public welfare, should be directed to the government. For the purpose of technology enhancement, the government should be able to ensure that any incoming technology to Indonesia is not an outdated or expired one and is environmentally friendly and secure, such that it will not become a burden to the country in the future. In addition, the government also needs to regulate technology transfer obligations for foreign technology investments, and for every technology-based project relating to the government.

To implement the constitutional mandate, future national regulations should be more explicit in regulating the responsibility of technology users to the country. In order to control the effect of technology utilization, i.e. supervision, the government can endorse mandatory auditing for the following activities:

1) Use of product technology for direct public services; for instance, public transportation and medical devices.
2) Use of production technology that has any potential negative effects to the public and country, such as disadvantageous environmental impact, explosive potential, also improvident energy use.

Furthermore, for the purpose of advancing technology, the government could also apply mandatory auditing for the following activities:

1) Management of national technology assets, especially in state-owned companies.
2) Technology-based industrial activity which are funded by the government, or in the process of application for facilitiesfrom the government;
3) Investment and foreign technology activity relating to governmental interests, to ensure technology transfer to domestic partners and thus synergized national technology ability.

The intent of mandatory technology auditing in this proposed concept is to develop national technology capability and technology self-sufficiency. To do so, the government needs to legally establish that results from mandatory technology audits are binding and imply, at the very least, a pursuant administrative decision. With such regulation, the implementation of national technology auditing can be classified as voluntary or mandatory. The government currently encourages voluntary technology auditing as an effort to increase added value and advancement of technology to achieve the organization's aim with regard to technology users; its implementation is fully handed over to technology user. However, the government should also implement mandatory technology audits to protect the public against negative effects from technology application and to facilitate national technology capability. Finally, it is expected that such proposed policy can become a conducive instrument for the government to improve public welfare and to enhance national competitiveness. This policy construction task would fall to the government and/or politicians.

Most current models used to evaluate the performance rate of technology-based business

organizations (e.g. return on investment) were developed mainly on the basis of the added value function in the past, and thus do not accommodate for valuation of technology asset status on future business. This shows that the current concept of the technology-based business organization that is used for evaluation does not give enough appreciation to the technology investment and thus does not adequately support the current advancement of science and technology. This concept could be potentially unproductive for long-term business competitiveness and national technology empowerment. Meanwhile, future national business regulations should establish a compulsory requirement for technology-based companies that seek to enter the capital market to give objective information on their technology valuation to the stock buyer. Such objective information shall come from the independent and competent technology auditors.

B. Implementation Tools

The implementation of a mandatory technology auditing policy accompanied by binding results could potentially have a significant impact on the sustainability of product and/or production technology operation, particularly when the object of the technology audit is related to a high-value investment or a huge labor engagement. Therefore, the conclusion of technology audit results must be based on objective fact and come from independent and competent technology auditors. In other words, the application of mandatory audits should be accompanied by the requirement of guaranteed technology auditor competence through institutional accreditation, which show auditors are able to work under a code of ethics including the values of independence, competence, objectivity, and integrity. In short, the development of any future national mandatory technology auditing are to be accompanied by an effort to build national technology audit capability, including the competence of technology auditors.

The effort to develop national technology auditing ability will need to be supported by tool and institution readiness. Said tool may include norms or a code of ethics, standards, procedure and manual (NSPM) that are agreed upon by all stakeholders. This would be a task for scholars, particularly those in the auditing community: to build the NSPM. Based on the NSPM, auditor competence and technology and audit methodology can be standardized, such that the technology audit results do not have multiple or ambiguous interpretations. Besides having clear regulations and suitable NSPM, the development of professional technology auditing needs institutions that have the capacity to facilitate and endorse standard formulation, provide knowledge and training to candidate auditors, and also test and certify auditor competence. Moreover, to assure the accountability of result, technology audit should not be conducted by any individual auditor, but by a legal and accredited institution. Furthermore, to build the professionalism of technology auditors, there should be an auditor association body that works toward auditor excellence, such as raising acknowledgment, empowering codes of conduct, bridging technology auditor interest with the government, and also providing legal aid to the technology auditors. At the end, based on the readiness of these infrastructures, national technology auditing should represent a systematic and objective evaluation that is conducted by technology auditors on technology assets in order to provide an added value to the auditee or any interested party.

C. Technical Concept on Objects of Technology Audit

If the audit is conceived as an evaluation or an analysis activity, then technology is the object of evaluation or analysis. The literature has shown that the definition and understanding of technology is very broad and depends on the perspective and context. Development of the concept of technology auditing as a standard procedure or as a binding tool should have a firm grasp on what technology is. So far, the concept of technology auditing gives no specific limits to what is considered to be technology. By taking a definition and understanding of technology as described in previous sections for reference, and for the purpose of concept development of technology auditing, this article proposes that technology,

as the audit object, is to be classified into three areas, i.e. i) product technology, ii) production technology, and iii) management of technology. Product technology as a specific object relates to design and can be viewed as a basis for the value of related products, as an independent object, and as part of a system as well. Production technology as a specific object relates to a planned activity that transforms input into output, which includes production tools and production value process chains in a production organization. As for management technology, this specific object refers to organizational functions that relate to the utilization effort on the whole technology element to build capability and organization competitiveness, for short term and long term, particularly as relating to innovation systems. The scope of each technology element according to the proposed technology audit objects can be illustrated in matrix, as shown in Table 1.

Furthermore, based on its function, product technology can be categorized into: i) end-user products (car, computer, etc.); ii) capital products (boiler, machines tools, etc.); and iii) intermediate products (steel sheets, aluminium ingots, etc.). Evaluating product technology as the object of audit will involve evaluating attributes related to its performance and quality such as efficiency, capacity, durability, reliability, conformity to specifications, serviceability, and safety. Meanwhile, evaluating production technology will involve evaluating attributes related to its production process performance such as efficiency, effectiveness, and productivity. Finally, evaluating management of technology as the specific object of the technology audit will involve evaluating attributes related to its competitiveness and organizational performance, especially those concerning the future of the business, such as technology capability, patents, networks, innovation, time to market, and technology leadership. This concept of the objects of technology auditing should thus be incorporated into the tools of implementation.

Table 1.
Relationship between Technology Object and Technology Element

Technology element				Technology object
O	I	H	T	
			V	Product technology
V	V	V	V	Production technology
V	V	V		Management of technology

Index:
T: Technoware; H: Humanware; I: Inforware; O: Orgaware

V. CONCLUSION

Indonesia's constitution has provided a basic philosophy for developing national technology audits, and Indonesian laws have stipulated the implementation of technology auditing and the development of the national technology audit capacity. Therefore, there is no reason for the government or the Indonesian society to not develop a suitable system of national technology auditing. The system should endorse policies for mandatory technology auditing, to ascertain the benefit of technology utilization for public welfare, advancement technology, and nation self-sufficiency. All parties (i.e. government bodies, politicians, industry, and the public) should be involved and support the conceptual development and implementation of national technology audits. The sustainability of future national technology auditing policy requires regulation clarity and strengthening, infrastructure readiness, and professionalism in implementation. Considering the current government agenda to increase technology investment, implementation of technology auditing should aim at harmonization between technology user interest, the public, and the government. Technology auditing will only yield benefit if it is implemented nationally. However, the effectiveness of a national technology audit policy requires intensive socialization and a gradual implementation that will co-evolve with the infrastructure readiness and urgency in the technology sector.

REFERENCES

Abetti, P. A. (1989). *Linking technology and business strategy*. New York: Presidents Association, Chief Executive Officers Division of American Management Association.

Anderson, L. S. (2004). *Technology audit survivor's guide*. Technical report. Mississippi: National Center for Technology Planning.

Baumgartner, F. R., & Jones, B. D. (1991). Agenda dynamics and policy subsystems. *The journal of Politics*, *53*(4), 1044–1074.

Braun, E. (1995). *Futile progress: Technology's empty promise.* London: Earthscan.

Braun, E. (1998). *Technology in context: Technology assessment for managers*. New York: Routledge.

Castells, M. (2004). Informationalism, networks, and the network society: A theoretical blueprint. In *The network society: A cross-cultural perspective*, pp. 3–45. Northampton, MA: Edward Elgar.

Chiesa, V., Coughlan, P., & Voss, C. A. (1996). Development of a technical innovation audit. *Journal of Product Innovation Management*, *13*(2), 105–136.

Cook, T. (2005). *Technology transfer - The Oxford experience* [Lecture]. Retrieved from https://sangakukan.jp/journal/journal_contents/2005/10/articles/0510-11/shiryo/0510-11siryo_e.pdf.

Daim, T. (1997). A review of evaluation of attributes for selecting advanced manufacturing technologies. In *Portland International Conference on Management and Technology*. Portland, O.R. doi:10.1109/picmet.1997.653330

Dolinšek, S., Janeš, A., Ćosić, P., & Ekinović, S. (2007). Development of the technology audit model. In *Management International Conference of the Faculty of Management Koper, MIC 2007*.

Drucker, P. F. (1985). *Innovation and entrepreneurship: Practice and principles*. New York: Harper and Row.

Ford, D. (1988). Develop your technology strategy. *Long range planning*, *21*(5), 85–95.

Fraunhofer. (2005). *Technology rating*. Materials prepared for cooperation discussion between BPPT and Fraunhofer Indonesia. Unpublished project proposal document.

Garcia-Arreola, J. (1996). Technology effectiveness audit model: A framework for technology auditing. (Master's thesis), *University of Miami*.

Hall, C. (2011). A typology of governance and its implications for tourism policy analysis. *Journal of Sustainable Tourism*, 19(4/5), 437–457. (http://dx.doi.org/10.1080/09669582.2011.570346).

Howlett, M., Ramesh, M., & Perl, A. (1995). *Studying public policy: Policy cycles and policy subsystems* (*Vol. 3*). Toronto: Oxford University Press.

Kelessidis, V. (2000). *Technology audit*. Report produced for the EC funded project. Innoregio. Thessaloniki Technology Park.

Khalil, T. M. (2000). *Management of technology: The key to competitiveness and wealth creation*. New York: McGraw-Hill Science, Engineering & Mathematics.

Kjaer, A. (2004). *Governance*. Cambridge: Polity Press.

Kooiman, J. (2003). *Governing as governance*. Los Angeles: Sage.

Kozel, C. T., Kane, W. M., Hatcher, M. T., Hubbell, A. P., Dearing, J.W., Forster-Cox, S., ... & Goodman, M. (2006). Introducing health promotion agenda-setting for health education practitioners. *Californian Journal of Health Promotion, 4*(1), 32–40.

Leonard, D. (1998). *Wellsprings of knowledge: Building and sustaining the sources of innovation*. Boston MA: Harvard Business School Press.

Martino, J. P. (1994, May). A technology audit: Key to technology planning. In *Aerospace and Electronics Conference, 1994. NAECON 1994., Proceedings of the IEEE 1994 National* (pp. 1241–1247). IEEE. (https://doi.org/10.1109/NAECON.1994.332899).

McCombs, M., & Reynolds, A. (2002). News influence on our pictures of the world. In J. Bryant & D. Zillmann (Eds.), *Media effects: Advances in theory and research.* (pp. 1–18). New York: Lawrence Erlbaum Associates.

Miao, L., & Jun, S. (2000). SWOT investigation of China's science and technology planning system in the new millennium. In *Management of Innovation and Technology, 2000. ICMIT 2000. Proceedings of the 2000 IEEE International Conference on* (Vol. 1, pp. 367–371). IEEE.

Mulyadi. (2002). Pengertian auditing menurut ahli [*Understanding of auditing according to experts*]. Retrieved March 11, 2016 from http://ilmuakuntansi.web.id/pengertian-auditing-menurut-ahli//.

Narayanan, V. K. (2001). *Managing technology and innovation for competitive advantage*. Delhi: Pearson Education.

Nataatmadja, J. H. (2015). Management of technology education for the betterment of Indonesia. Paper for the *Indonesia-Japan Symposium on Management of Technology (MoT)*. Institut Teknologi Bandung (SBM ITB) and Yamaguchi University Management of Technology (YUMoT). Bandung, 10th September 2015.

Peters, B.G. (2000). Governance and comparative politics. In J. Pierre (Ed.), *Debating governance: Authenticity, steering and democracy*, pp. 36–53. Oxford: Oxford University Press.

Pierre, J., & Peters, B. G. (2000). *Governance, politics and the state.* New York: St. Martin's Press.

Pierre, J., & Peters, B. G. (2005). *Governing complex societies: Trajectories and scenarios*. Basingstoke: Palgrave.

Porter, M. E. (1998). *On competition*. Boston: Harvard Business School Publishing.

Putera, P. B. (2012). Perspektif system inovasi dalam konten kebijakan daerah JawaTimur bidang iptek dan inovasi periode 2000–2011 [*The perspective of innovation systems on regional policy content of East Java in the field of science-technology and innovation in the period of 2000–2011*]. *Warta KIML10*(2), 83–94.

Rhodes, R. A. W. (1997). *Understanding governance: Policy networks, governance, reflexivity and accountability.* Buckingham: Open University Press.

Rogers, E. M., & Dearing, J. W. (1988). Agenda-setting research: Where has it been? Where is it going?" *Communication Yearbook 11*, 555–594. Newbury Park: Sage. (http://dx.doi.org/10.1080/23808985.1988.11678708).

Schwab, Klaus (ed.). (2016). *The global competitiveness report 2016–2017*. Geneva: The World Economic Forum. (www.weforum.org/gcr).

Sharif, N. (1989). *Technology for development.* Bangkok: UNESCAP.

Shirazi, S. Z. (2009). The possibility of industrial management using technology audit model in the public sector engineering units of Pakistan. *Journal of Information & Communication Technology 3(*1), 21–28.

Štrukelj, P. and Dolinšek, S. (2010). In search for a fundamental structure of technology and its management in modern high-tech companies. *Social Responsibility, Professional Ethics, and Management. Proceedings of the 11th International Conference.* Ankara, Turkey, 24–27 November 2010.

Tjokroamidjojo, B. & Mustopadidjaja, A. R. (1998). *Kebijaksanaan dan administrasi pembangunan* [*Development policy and administration*]. Jakarta: LP3ES.

Yam, R. C., Guan, J. C., Pun, K. F., & Tang, E. P. (2004). An audit of technological innovation capabilities in Chinese firms: Some empirical findings in Beijing, China. *Research Policy*, *33*(8), 1123–1140. (https://doi.org/10.1016/j.respol.2004.05.004).

Yee, A. S. (2004). Cross-national concepts in supranational governance: State–society relations and EU policy making. *Governance*, *17*(4), 487–524. (https://doi.org/10.1111/j.0952-1895.2004.00255.x).