POLICY MODELLING FOR THE DEVELOPMENT OF UNMANNED AIRCRAFT SYSTEM INDUSTRY IN INDONESIA USING SYSTEM DYNAMICS METHOD

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ABSTRACT

The unmanned aircraft system (UAS) industry in Indonesia is lagging behind in market share and innovation. An effective government policy is crucial to make domestic UAS products more innovative and competitive. However, still not enough academic research discusses the system structure of the UAS industry. Considering the complexity of the UAS industry, this study uses system dynamics in combination with a policy analysis framework to capture a broader perspective on the system. The conceptual model showed that a policy structure to shift customers from imported products to domestic products may help the development of the UAS industry and advance UAS technology.

OPSOMMING

Die bedryf vir onbemande vliegtuigstelsels (UAS) in Indonesië is agter met betrekking tot markaandeel en innovasie. 'n Effektiewe regeringsbeleid is van kardinale belang om binnelandse UAS-produkte meer innoverend en mededingend te maak. Daar is egter steeds nie genoeg akademiese navorsing wat die stelselstruktuur van die UAS-industrie ondersoek nie. Met inagneming van die kompleksiteit van die UAS-industrie, gebruik hierdie studie stelseldinamika in kombinasie met 'n beleidsontledingsraamwerk om 'n breër perspektief op die stelsel vas te lê. Die konseptuele model het getoon dat 'n beleidstruktuur om klante van ingevoerde produkte na binnelandse produkte te verskuif die ontwikkeling van die UAS-industrie kan help en UAS-tegnologie kan bevorder.

1. INTRODUCTION

Over the past few years, unmanned aircraft systems (UAS) have become a disruptive technology worldwide [1]. UAS, also widely known as drones or unmanned aerial vehicles (UAVs), are aircraft that have no onboard human pilot and are remotely controlled by a pilot on the ground [2]. As UAS technology continues to evolve at a rapid pace, there is a broad spectrum of UAS types [3] that contribute to Industry 4.0 through their efficiency and effectiveness [4]. UAS are used to address various societal and industrial needs, in particular aerial photography, shipping and delivery, disaster management, precision agriculture, and entertainment [5]. It offers tremendous benefits, such as reducing labour costs [6], reducing delivery times [7], generating a low environmental imprint [8], and giving a good return on investment [9].

The nature of its commercial and industrial use unlocks business and innovation opportunities for the local manufacturing industry [10]. As a result, the number of industries gaining benefits from this technology is increasing. The UAS market has witnessed strong growth in the past few years, and is predicted to have positive growth globally until 2030 [11]. In Indonesia, the UAS sector is a sunrise sector with a robust demand for UAS applications in multiple fields, including agriculture, construction, and mining. According to national market outlook research, the UAS market in Indonesia is projected to have a compound annual growth rate (CAGR) of 8.1% in the coming years, having reached a value of around 320 billion Rupiah in 2023 [12]. The increasing array of UAS applications accelerates market growth. Local UAS industries are playing an important role in meeting domestic demand. In fact, foreign-made UAS are flooding the market, and are preferred owing to the lack of high-quality domestic alternatives. Consequently, Indonesian-made UAS products still have a low share [12].

The government of Indonesia announced that the UAS industry is a part of the aviation sector, which is categorised as a national priority programme. In propelling this nascent business industry, the government of Indonesia released a roadmap for the development of the Indonesian aerospace industry ecosystem [13]. The UAS industry in Indonesia is lagging behind in market share and innovation; but with this roadmap, the government intends to make domestic UAS products more innovative and competitive. The indigenous UAS industry's development could promote innovation and drive economic growth. Therefore, an effective policy adopted by the government would be crucial to bolstering its development. In addition to that, policymaking to push the UAS industry has also become a main concern in other countries, such as a production-linked incentive (PLI) policy in India that is aimed at strengthening national manufacturing capacity [14], a technology policy in the United States to make it a leader in global UAS technology [15]; and an industrial policy in South Korea to fuel the growth of the domestic UAS industry [16].

Previous scholarly work has resulted in several policy recommendations [17], [18], [19], [20], [21] that have emphasised governing and standardising the deployment of UAS from a safety and security standpoint; however, aspects of technology policy that are concerned with encouraging technological advancement and industrial development in the field of UAS have received little attention so far. For that reason, this paper aims to explore Indonesia's national policy structure for developing a profitable UAS industry and advancing UAS technology. The dynamic complexity in the industry's environment as a result of multiple involved actors and factors, uncertainties about government regulations, and the normative dimensions of UAS operations makes it suitable to combine the system dynamics approach [22] and a policy analysis framework [23]. The system dynamics method helps to gain insight into the underlying structure of and dynamic relationships between elements in the industry, while the policy analysis framework assists policymakers in choosing the most preferred policy alternative. This study aims to address a research gap in the literature, since no past publications cover the same topic and apply the same method.

The remainder of this paper is structured as follows. Section 2 provides a literature review of the complexity of the UAS industry and the development of UAS technology. Section 3 explains the methodology of this study. Section 4 provides the results and a discussion of them. Section 5 concludes the study with some recommendations.

2. LITERATURE REVIEW

2.1. The complexity of the UAS industry

The UAS industry in Indonesia is a complex socio-technical system with multiple actors. The number of actors and their differences in interests, objectives, and ambitions create the complexity. For commercial and industrial products, the UAS industry is predominantly composed of small and medium enterprises

(SMEs) as manufacturing actors. To date, around 104 legitimate companies have emerged in the country, consisting of manufacturers, distributors, and service providers [12]. Overall, for each indigenous UAS manufacturer there are three UAS distributors and service providers. Despite their home factory stage, UAS manufacturers have adequate capability in designing and manufacturing [24]. They are also capable of tailoring their products to the specific needs of Indonesian industries.

In 2021, the number of UAS in Indonesia encountered massive growth, reaching 100,000 units for civilian applications. The government of Indonesia, as the regulatory actor, is committed to facilitating legalised UAS operations across the country while ensuring that they do not violate the safety of people, buildings, and civil aircraft, even though in other countries a high number of occurrences have been reported by the Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA) [25]. The government of Indonesia establishes a regulated and safe airspace for UAS through clear national regulations. Three specific regulations affecting UAS design and operation were introduced: Ministry of Transportation regulations numbers 37/2020, 34/2021, and 63/2021. These regulations have been periodically revised in recent years and updated to keep pace with the increasing operation and technology of UAS. The regulations require all products to be registered and certified by the government. The implementation of these regulations may drive innovation on the one hand, but may impede innovation on the other [18]. I neffective regulations can also reduce UAS demand, limit their operation, and hinder UAS technological innovation that could provide economic benefits for Indonesian industries [26]. The constantly changing national regulation landscape that manages pilots' licences , UAS registration and certification, and flying zones may influence the UAS adoption process. However, regulation remains a pivotal factor, so it should balance safety with the need for innovation. Last, the end user and the public role should be considered, which may add to the complexity [24].

The interconnected factors involving design and engineering, test and certification, production, sales, and finances can be found in the civil aircraft industry structure [27]. Given the high degree of commonality between civil aircraft and UAS technology, these internal factors and their interrelationships create a dimension of complexity in the UAS industry. According to another study, the growth of the UAS industry may be driven by five main factors: infrastructure, regulation, technological capabilities, public acceptance, and economic drivers [28]. Further, the societal implications of UAS operation for the areas of privacy, peace, ethics, and data protection increase the complexity of the normative dimension [29], [30]. Considering the complexity and dynamics of the UAS industry, a system dynamics approach based on a broader perspective is required.

2.2. The development of UAS technology

UAS technology has improved rapidly, especially in respect of capabilities and flight duration. The development of UAS technology follows the technology development phases of concept, basic research, applied research, design and engineering, manufacturing, marketing, and product. The design and engineering process may be executed in-house or by creating development partnerships with other institutions, whether commercial companies or research organisations. The technological collaboration can reduce development time and remove technological barriers [31], while the transfer of technology from international UAS producers may decrease the capability gap between those developed companies and nascent domestic companies.

The appropriate framework is essential for industries in order to develop UAS technology [32]. They may implement development strategies that are either user-oriented or use product facilities [33]. The final integrated design has to undergo tests and certification to obtain approval from local authorities before it enters the production stage. The ground and flight tests are to ensure the flight reliability and product airworthiness mandated by the regulations [34]. Aviation safety regulations manage the guidelines and processes for UAS-type certification [35], which is mandatory for several types of UAS [36]. Delays in the certification process may extend the time for the product's introduction to the market; however, unproven and uncertified UAS products may be unattractive for some customers. The technology, material, production method, and test and certification process may vary among products.

Depth of know-how and an experienced workforce, as well as cutting-edge technology, are required in order to create innovative UAS products [28], [37]. These cutting-edge products would certainly give bring competitive advantage and greater attractiveness to the UAS markets [38]. Some strategies could be implemented by UAS manufacturers to develop breakthrough technologies [39]. However, some of the most novel designs and technologies take a longer lead time to develop and to gain approval [28]. Nonetheless, it is important that innovation in the UAS world is not at odds with the authorities' efforts to ensure safety.

Understanding the dynamics process of UAS technology development is vital in order to sustain the continued level of innovation growth [40].

3. METHODOLOGY

This study applied a system dynamic modelling method and policy analysis framework to formulate a conceptual model of the UAS industry in the form of a system diagram. The system dynamics method has the capability to analyse complex and dynamic systems – for example, in the civil aircraft industry [27], the electric vehicle and battery industry [41], and the SME industry [42]. The policy analysis framework has the capability to evaluate policies for technology development and adoption – for example, in rooftop photovoltaics adoption [43], electric vehicle adoption [44], and energy technology adoption [45]. The system diagram based on the conceptual model is developed as part of problem structuring. Generally, it consists of the problem owner and its main goal, the system's outcome of interest, a variety of actors or stakeholders, policy instruments, external factors, and a causal loop diagram (CLD) [46]. The CLD helped the researcher to understand the causal influences and the power of feedback between endogenous factors in the UAS industry [47].

3.1. Actor analysis

First and foremost, it was necessary to identify the network of actors and their involvement in the system. Actors are a combination of a problem owner and relevant stakeholders. The relevant actors can be divided into four categories: (1) those affected by the problem situation and by the solution being considered; (2) those having influence in the problem situation; (3) those who are required for the implementation of the solution; and (4) those formally participating in the policymaking [48]. Naturally, different actors have different goals and interests in the system. Therefore, collaborative effort is needed to reach the stated system's goal, in that each actor has a critical role to play. Five diverse actors are connected in the UAS industry: (1) the government of Indonesia as the problem owner; (2) the small and medium enterprises (SMEs) making up the UAS industry; (3) academic institutions as the educators and researchers; (4) the air navigation service provider company as the regulator of the national airspace; and (5) those who are typical UAS users. The actor analysis elaborates on the characteristics of these actors in respect of the following:

- The problem perception – the gap between the actors' objective and the current situation.
- The root cause of the problem from the perspective of each actor.
- The respective actors' internal interests and objectives.
- Tangible and non-tangible resources from each actor to influence the situation.
- The actors' likely position in viewing the problem situation.

Table 1 and Table 2 summarise the actors' characteristics and their conduct in the context of the UAS industry in Indonesia. The actor analysis is briefly described below.

Table 1: Actors' problem perceptions and objectives

Actor	Problem perception	Cause of problem	Objective
Government of Indonesia	The UAS industry is key to the national economy, but it is not followed by the advancement of domestic products	Lack of attractiveness of domestic products	To master UAS technology through a profitable UAS industry
Small and medium enterprises	Lack of interest in domestic products, leading to bankruptcy	Low trade protection for domestic products	To provide products that meet market needs
Academic institutions	Knowledge and capability in UAS technology have not been applied to the UAS industry	Lack of collaboration between academic institutions and UAS industries	To increase knowledge and capability through education about and research into UAS technology

Actor	Problem perception	Cause of problem	Objective
Air navigation service provider company	An increased risk for aviation safety and security	Limited policies and regulations governing UAS operation	To prevent UAS-related incidents and accidents
Users	An increased need for products, but a lack of information about applicable regulations	Limited information about domestic products and limited events related to explanation of regulations	To use products in accordance with needs and regulations

Table 2: Actors' interests, resources, and positions

Actor	Interest	Resource	Position
Government of Indonesia	The growth of the economy and mastery of technology	Power to conduct research and implement policies	Research key technology and arrange effective policies
Small and medium enterprises	A profitable and sustainable business	Power to design, develop, and manufacture products	Design and develop products based on internal capability and market demand
Academic institutions	Advancement in education and research	Power to provide education and conduct research	Provide education and conduct research based on institutional capability
Air navigation service provider company	The aviation safety and security standard	Power to control Indonesian airspace	Monitor UAS use and report its misuse
Users	Reliable product and stable regulations	Power to purchase imported products and avoid domestic products, or vice versa	Look for products that fit their needs and budgets

The first factor is the government of Indonesia, which is the problem owner. The government is highly interested in economic growth and in technological mastery. However, the government notes the current situation in which the UAS industry's growth is not followed by technological advances in domestic products. The lack of technological innovation is hindering the attractiveness of domestic products. Currently, the government is more focused on key technology research and effective policy arrangements [49].

The second actor is the small and medium enterprises (SMEs), which are the backbone of the UAS industry in Indonesia. The industry tries to provide products that meet market needs in order to make a profit for sustainable businesses. However, the SMEs note some lack of interest in their products. A low level of trade protection for national products makes imported products more attractive for customers [12], yet SMEs have the resources to design, develop, and manufacture domestic products.

The third actor is the academic institutions that are the educators and researchers in UAS technology. Academic institutions are interested in advancing education and research. Therefore, academic institutions are willing to increase knowledge and capability through education and research in UAS technology. Unfortunately, this knowledge and capability has not been widely applied in the UAS industry. The lack of collaboration between academic institutions and the UAS industry is the main issue. Academic institutions continue to provide education and to conduct research based on their institutional capability.

The fourth actor is the air navigation service provider company, which is the air traffic control authority. Aviation safety and security standards are the main interests of the air navigation service company. Therefore, its objective is to prevent UAS-related incidents and accidents. Since UAS have become more accessible and affordable, their widespread use, especially those products that are low-quality and unsafe, increases the risk posed to air traffic [50]. This happens due to limited UAS-related policies and regulations governing its operation. The company uses its airspace control capability to monitor and report the misuse of UAS.

The final policy actor is typical UAS users, who aim to use UAS based on their needs but also responsibly and in compliance with the applicable regulations. Thus these users need reliable UAS technology and stable UAS regulations. Users are in the position to select products that meet their budgets and needs. They can choose domestic products over imported products, or vice versa. The perceived problem is that, while the need has increased, there is a lack of information about the applicable operational regulations. This happens because of limited information about domestic products and limited events for an explanation of the regulations by the authorities.

3.2. Model conceptualisation

Qualitative data from previous studies related to the UAS industry and technology was used in the modelling process. Policy instruments and external factors served as input for the model. Policy instruments can be either fiscal or non-fiscal policies about the types of taxes, subsidies, and regulations. Policy instruments are governance tools to direct the model's behaviour in order to meet the problem owner's goal. Such available measures are tax incentives [51], import tariffs [52], and a preference for domestic products in the procurement process. The imported product base price, innovation rate, and manufacturer, the process time for design and engineering and for test and certification, and the growth in demand become the external factors. The problem owner has no control over these factors. Nonetheless, they create uncertainty in the behaviour of the system.

The CLD describes the causal relationships between factors or elements in the UAS industry's development. This study used Vensim to develop the CLD. This industry has both economic and technological importance for Indonesia. Therefore, the objective would be to master the UAS technology through a profitable UAS industry. Four relevant criteria were selected to measure each policy intervention's effectiveness: 1) the domestic product type; 2) the domestic product volume; 3) the industrial profit; and 4) the domestic product manufacturer. The system demarcation that follows limited the system under study: This model only included the industry that was capable of manufacturing UAS; UAS products in all types and weights were considered as an aggregate in the model; and the export of UAS products to international markets was negligible . The detailed system diagram showing the current situation in the UAS industry is presented in Figure 1, and an enlarged version of the CLD is provided in Figure 2.

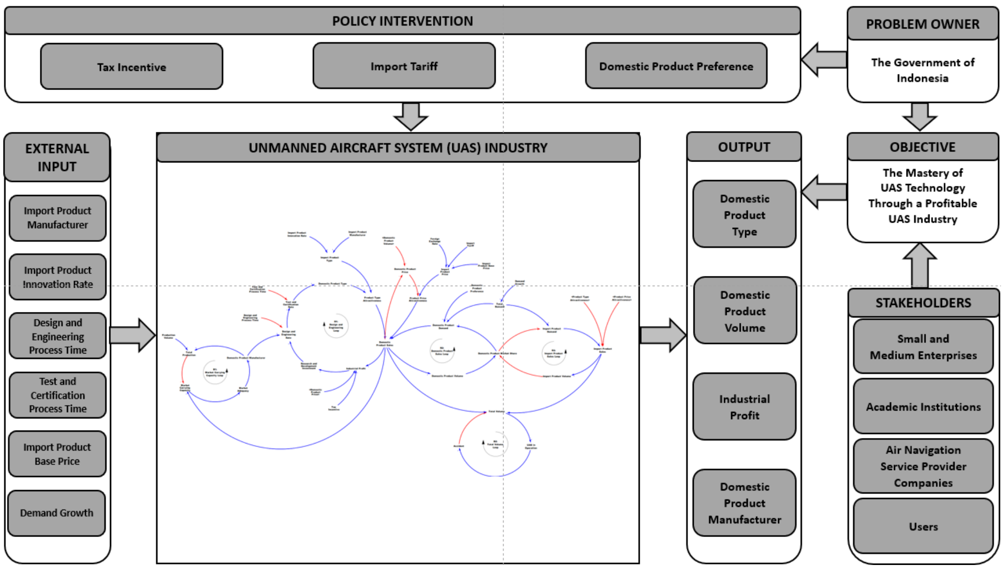

Figure 1: System diagram of the UAS industry in Indonesia

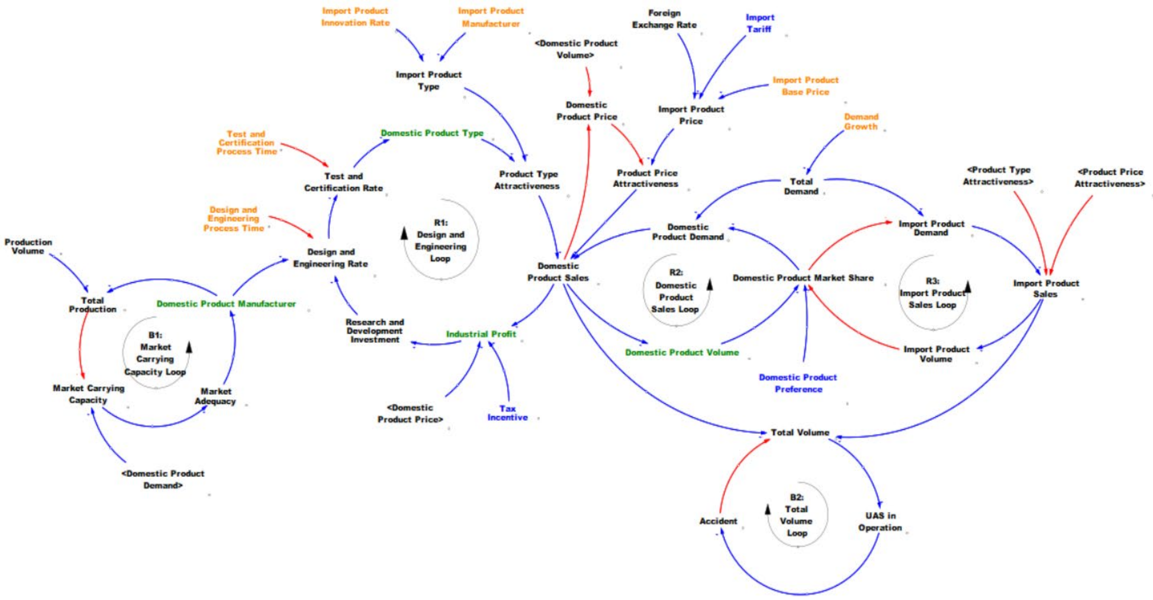

Figure 2: Causal loop diagram of UAS industry in Indonesia

4. RESULTS AND DISCUSSION

4.1. The causality of market-carrying capacity for domestic product manufacturers

Figure 3 shows the first feedback process in which the number of domestic product manufacturers is affected by the market-carrying capacity [42]. Domestic product demand and sales increase the market-carrying capacity; in contrast, the total production from all domestic product manufacturers decreases. The changing capacity of the market influences market adequacy, which has a relationship with domestic product manufacturers. The polarity of both variables is positive, which means that a higher market adequacy would motivate newer entrants to enter the market, but that the increasing number of new industries would lower the market adequacy, which in turn could lead to a decline in the number of industries. This causality process creates a balancing feedback loop.

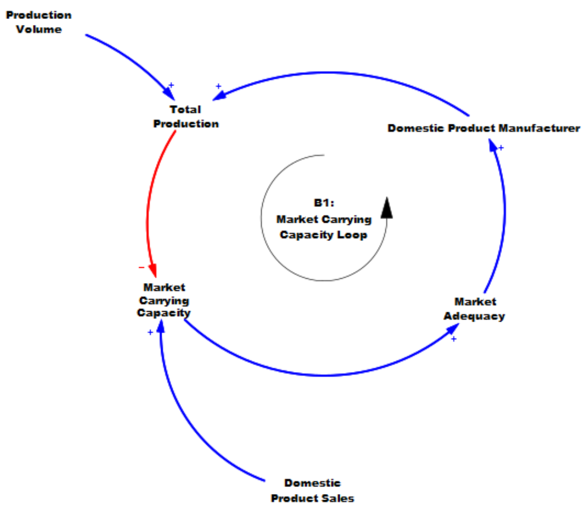

Figure 3: The first feedback process

4.2. The causality of design and engineering intensity for domestic product type and industrial profit

Figure 4 shows the second feedback process in which the number of domestic product types and the industrial profit are affected by the intensity of design and engineering. The increased activities of design and engineering in the UAS industry would send more products to the test and certification floor, and so would release a wider range of certified domestic product types to the market, which would be indicated by a positive polarity for both variables. However, it should be noted that exogenous factors such as the longer design and engineering process times required by the manufacturers and the longer test and certification process times required by the local authority may delay the introduction of the product, as shown in the incoming arrows with negative polarities in Figure 4. In theory, various types of domestic product offerings may raise the attractiveness of the product type by giving the customer more choice in addressing their needs; and eventually that could raise the local industry's sales. The higher volume of sales would generate a significant profitability for the industry, and the cash flow could be reinvested in subsequent design and engineering activities in innovating new indigenisation products. Provided that the polarity of all variables is positive, this reinforcing feedback loop would either become stronger by generating more product types and profits, or deteriorate if one of the variables underperformed.

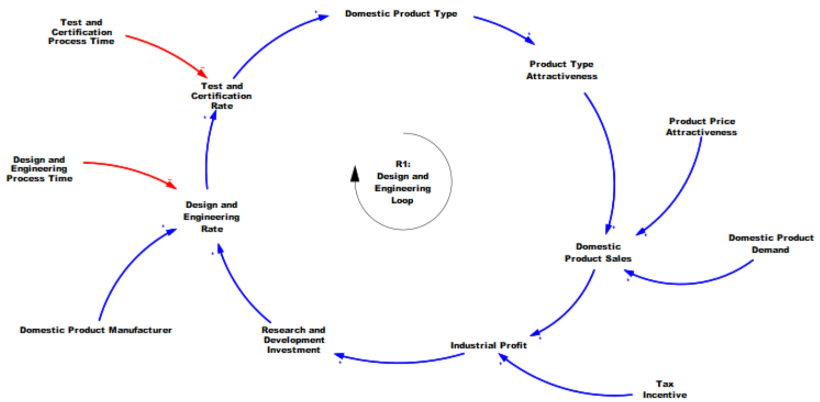

Figure 4: The second feedback process

4.3. The causality of domestic and imported product sales for market share

Figure 5 shows the third feedback process, in which the market share is affected by changes in the domestic and imported product sales. The market share influences the demand and then the sales. If the domestic product market share expands, the domestic product demand and sales will follow. Conversely, the imported product demand and sales will fall; and if the domestic market share narrows, the imported product demand and sales will increase correspondingly. The growing domestic product market share would create successful product sales, whereas the loss of its share would weaken the domestic industry. This loop resembles the 'success to the successful' archetype [53]. Product attractiveness may become a determining factor in domestic product sales, and the attractiveness would come from product type and product price. The type attractiveness would be measured by comparing the number of domestic product types with the number of imported product types. The number of imported product types is increasing globally owing to the innovation rate of foreign manufacturers, while price attractiveness would compare the domestic and imported product prices. It is assumed that more product choices and lower product prices would drive customers' decisions in selecting domestic products in a positive direction.

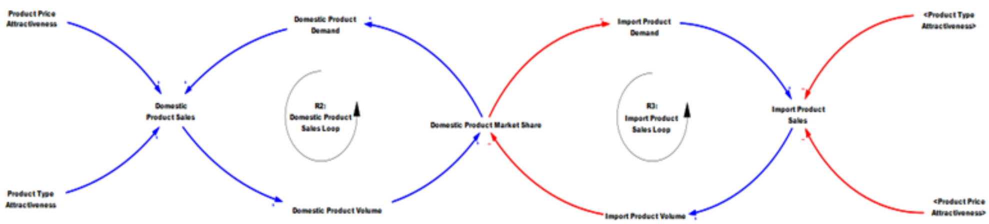

Figure 5: The third feedback process

4.4. The causality of domestic and imported product sales for the number of accidents

Figure 6 shows the fourth feedback process in which the number of accidents is affected by the total product sales. Domestic product and imported product sales contribute to the total volume of UAS owned by their eventual users. This volume would affect the number of UAS in operation. The polarity of these variables is positive, which means that more sales send more UAS into the sky. Unavoidably, the risks of UAS falling on people and buildings on the ground and of midair UAS collisions would increase, resulting in a higher number of accidents. These safety management problems are a common issue around the world. A post-accident analysis study conducted in a neighbouring country revealed that UAS technical malfunction is the highest factor [54]. Operations that are not compliant with the applicable regulations may increase these numbers. The Joint Authorities for Rulemaking on Unmanned Systems (JARUS) developed a standard risk assessment methodology, the specific operations risk assessment (SORA), which is suitable for identifying and mitigating the potential risk of every UAS operation [55]. These accidents, however, would lower the total number of UAS flown by users, creating a balancing feedback loop. Accidents are also detrimental to the public's acceptance of UAS operations.

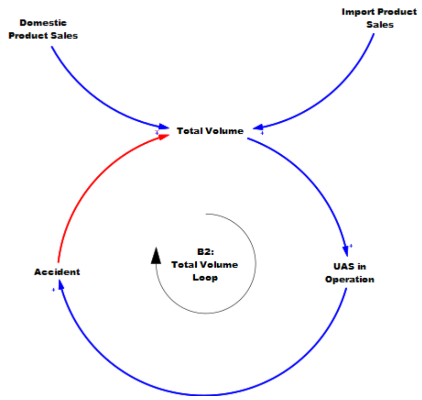

Figure 6: The fourth feedback process

4.5. Policy instruments for development of the UAS industry

The government of Indonesia has taken steps to formulate numerous policies that consist mainly of tax incentives, financial assistance, and preferring domestic products in the procurement process. However, there are still some areas for policy intervention or relaxation from the government. Given this context, this study explores three alternative policies, as listed at the top of the system diagram (Figure 1). The current tax incentive policy, found in government regulation No. 45/2019, is a great financial support for the UAS industry in Indonesia, and is instrumental in promoting research and development in Indonesia, for which a significant amount of the annual tax paid by companies is deducted. The deduction for research and development costs may be up to 300%. Highly intensive research and development could increase the number of domestic products and those products' competitiveness against imported products. To be more effective in supporting Indonesia's competitiveness against other nations, this tax credit policy should be extended to specific industries, just like the UAS industry [51].

The next applicable policy, import tariffs, is designed to protect the domestic UAS industry, and is supposed to limit the massive number of imported products by imposing tariffs on imported UAS products. Because of efficient production and mass sales, some top foreign producers are able to set relatively low base prices for their products [56]. If the government of Indonesia imposed a high import tariff on products imported from other countries, the selling price of these products would be more expensive because they would be subject to taxes and tariffs. As a result, users would prefer to purchase domestic products. The shift from imported products to domestic products is expected by SMEs. Therefore, this policy intervention would be essential to increase the cost competitiveness of domestic products and to create a level playing field in the face of imported products.

UAS technology has been widely used in various programmes and public services by the government of Indonesia [57]. However, there are still some obstacles to adopting this technology for public and private purposes [58]. The acceleration of commercial and industrial applications, especially using Indonesian-made UAS, is affected by the speed of the adoption process. Thus the national adoption of domestic products should be urged if the government were willing both to boost domestic production and to reduce the current overreliance on imports. The adoption process could be accelerated through a policy that pushed the preference for domestic products in the procurement process. The increased use of indigenously developed UAS could reduce production costs, thanks to a high volume of production. The affordable price may then raise the products' attractiveness and sales, and the higher volume of sales would generate a sufficient cash flow and profit margin for the industry to reinvest it in design and engineering programmes for increasing indigenisation products, skill-building programmes for creating a talented workforce, and infrastructure improvement programmes for speeding up the test and production process.

4.6. Alternative policy recommendations

Alternative sensible and conducive policies may be examined to come up with other subsidy schemes and incentive forms. A new form of incentive, such as manufacturing tax credits, may be provided by the government to encourage local industries to manufacture local content UAS components, such as batteries, airframes, and motors [59]. Local components would reduce the cost of the main components, which are still imported. This incentive may also overcome issues with the availability of raw materials, electronic components, and engines [60]. Another incentive could be dedicated to research grants or finance loans at low interest rates for pilot studies and technology demonstrations [61]. A stimulus for establishing active engagement and synergy between academia, research institutes, and industries in developing UAS technology would also be worth considering, as collaboration and knowledge-sharing among these actors could maintain the increased pace of innovation. A well-known policy in the industrial sector, the domestic content threshold, could also be expanded to have a broader coverage to include government, state-owned enterprises, and the private sector for hardware and software [12, 62]. This instrument would be beneficial in accommodating and leveraging local component content in UAS production.

Some challenges that still require government attention are the poor testing and certification infrastructure, inadequate regulations, technical and non-technical skill shortages, and the scarcity of qualified pilots, all of which potentially delay national industry and technology development. It would be essential for growth-oriented policies to allow flexibility in UAS innovation and to create a favourable environment in which the UAS industry could flourish. The government should work closely with industry stakeholders. Feedback from industries and the public about the proposed policies is necessary. With continuous investments in design and engineering, and with proactive support from the government of Indonesia, the UAS industry could grow and maintain a sustainable competitive edge against foreign competition. If the Indonesian UAS industry environment does not offer promise, international investments in UAS technology are likely to be directed to other potential countries.

5. CONCLUSION

The government of Indonesia and the UAS industry share a common goal in seeking to move the industry forward and to promote domestic technology. Attaining this goal would need more strong and supportive government policies. The government has assisted with the framework for investments, incentives, tariffs, and procurement preferences. However, the actual implementation of these policy instruments is different in its impact and effectiveness. Therefore, a policy structure to shift customers from imported products to domestic products may help the development of a sustainable UAS industry and the eventual advancement of UAS technology.

This research is not without its limitations. It is qualitative in nature, and focuses on only a preliminary study. It therefore calls for the future development of a quantitative model. Quantitative research could simulate either existing policies or new forms of policy that combine with historical data in order to test and evaluate the effectiveness of policy solutions in some plausible future scenarios. Based on the results, policymakers could make informed decisions about advancing the UAS industry and fostering its technological development. Future research topics could also take into account the public acceptance variable concerning UAS operation, which could add an interaction between this variable and UAS sales. Finally, even though this conceptual study focuses only on the UAS industry in Indonesia, the lesson learned from its findings is still relevant to the policymaking process in other countries with similar characteristics.

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REFERENCES

[1] S. J. Fox, “The ‘risk’ of disruptive technology today (A case study of aviation — Enter the drone),” *Technology in Society*, vol. 62, Feb. 2020. doi: 10.1016/j.techsoc.2020.101304

[2] R. Clarke, “Understanding the drone epidemic,” *Computer Law and Security Review*, vol. 30, no. 3, pp. 230–246, 2014. doi: 10.1016/j.clsr.2014.03.002

[3] M. Hassanalian and A. Abdelkefi, “Classifications, applications, and design challenges of drones: A review,” *Progress in Aerospace Sciences*, vol. 91, pp. 99–131, May 2017. doi: 10.1016/j.paerosci.2017.04.003

[4] M. Javaid, I. H. Khan, R. P. Singh, S. Rab, and R. Suman, “Exploring contributions of drones towards Industry 4.0,” *Industrial Robot*, vol. 49, no. 3, pp. 476–490, Apr. 2022. doi: 10.1108/IR-09-2021-0203

[5] A. A. Laghari, A. K. Jumani, R. A. Laghari, and H. Nawaz, “Unmanned aerial vehicles: A review,” *Cognitive Robotics*, vol. 3, pp. 8–22, Jan. 2023. doi: 10.1016/j.cogr.2022.12.004

[6] J. P. Aurambout, K. Gkoumas, and B. Ciuffo, “Last mile delivery by drones: An estimation of viable market potential and access to citizens across European cities,” *European Transport Research Review*, vol. 11, 30, Dec. 2019. doi: 10.1186/s12544-019-0368-2

[7] A. Smith, J. E. Dickinson, G. Marsden, T. Cherrett, A. Oakey, and M. Grote, “Public acceptance of the use of drones for logistics: The state of play and moving towards more informed debate,” *Technology in Society*, vol. 68, Feb. 2022. doi: 10.1016/j.techsoc.2022.101883

[8] J. Koiwanit, “Analysis of environmental impacts of drone delivery on an online shopping system,” *Advances in Climate Change Research*, vol. 9, no. 3, pp. 201–207. Sep. 2018. doi: 10.1016/j.accre.2018.09.001

[9] R. Luppicini and A. So, “A technoethical review of commercial drone use in the context of governance, ethics, and privacy,” *Technology in Society*, vol. 46, pp. 109–119, Aug. 2016. doi: 10.1016/j.techsoc.2016.03.003

[10] F. Giones and A. Brem, “From toys to tools: The co-evolution of technological and entrepreneurial developments in the drone industry,” *Business Horizons*, vol. 60, no. 6, pp. 875–884, Nov. 2017. doi: 10.1016/j.bushor.2017.08.001

[11] E. Alvarado, “Drone market analysis 2022-2030,” *Drone Industry Insights*, Sep. 20, 2022. Accessed: Feb. 21, 2024. [Online]. Available: https://droneii.com/drone-market-analysis-2022-2030

[12] D. Rusdiana, “Outlook industri drone Indonesia 2023,” *Asosiasi Sistem & Teknologi Tanpa Awak*, Nov. 21, 2022. Accessed: Feb 21, 2024. [Online]. Available: https://astta.id/2022/11/24/outlook-industri-drone-indonesia-2023/

[13] Kementerian PPN/Bappenas, “Peta jalan pengembangan ekosistem industri kedirgantaraan Indonesia 2022-2045.” Accessed: Feb. 10, 2024. [Online]. Available: https://perpustakaan.bappenas.go.id/e-library/file_upload/koleksi/migrasi-data-publikasi/file/Policy_Paper/Peta Jalan Ekosistem Industri Kedirgantaraan Indonesia 2022-2045.pdf

[14] S. R. Edulakanti and S. Ganguly, “Review article: The emerging drone technology and the advancement of the Indian drone business industry,” *Journal of High Technology Management Research*, vol. 34, no. 2, 100464, Nov. 2023. doi: 10.1016/j.hitech.2023.100464

[15] B. Skorup and W. Gu, “Drone policy and industrial policy in the United States and China: Comparisons and recommendations for American lawmakers,” Accessed: Feb. 8, 2024. [Online]. Available: https://www.mercatus.org/research/policy-briefs/drone-policy-and-industrial-policy-united-states-and-china-comparisons-and

[16] K. Sungjin, “The future of the Korean drone industry and policies for growth,” *KIET Industrial Economic Review*, vol. 28, no. 5, pp. 28–36, 2023. doi: 10.2139/ssrn.4620733

[17] P. K. Freeman and R. S. Freeland, “Politics & technology: U.S. polices restricting unmanned aerial systems in agriculture,” *Food Policy*, vol. 49, pp. 302–311, Dec. 2014. doi: 10.1016/j.foodpol.2014.09.008

[18] H. Nakamura and Y. Kajikawa, “Regulation and innovation: How should small unmanned aerial vehicles be regulated?” *Technological Forecasting and Social Change*, vol. 128, pp. 262–274, Mar. 2018. doi: 10.1016/j.techfore.2017.06.015

[19] R. Merkert and J. Bushell, “Managing the drone revolution: A systematic literature review into the current use of airborne drones and future strategic directions for their effective control,” *Journal of Air Transport Management*, vol. 89, 101929, Oct. 2020. doi: 10.1016/j.jairtraman.2020.101929

[20] M. Ayamga, B. Tekinerdogan, A. Kassahun, and G. Rambaldi, “Developing a policy framework for adoption and management of drones for agriculture in Africa,” *Technology Analysis & Strategic Management*, vol. 33, no. 8, pp. 970–987, 2021. doi: 10.1080/09537325.2020.1858047

[21] D. Lee, D. J. Hess, and M. A. Heldeweg, “Safety and privacy regulations for unmanned aerial vehicles: A multiple comparative analysis,” *Technology in Society*, vol. 71, 102079, Nov. 2022. doi: 10.1016/j.techsoc.2022.102079

[22] J. Sterman, *Business dynamics: Systems thinking and modeling for a complex world*. Boston: Irwin McGraw-Hill, 2000.
[23] W. E. Walker, “Policy analysis: A systematic approach to supporting policymaking in the public sector,” *Journal of Multi-Criteria Decision Analysis*, vol. 9, no. 1–3, pp. 11–27, 2000. doi: 10.1002/1099-1360(200001/05)9:1/3<11::AID-MCDA264>3.0.CO;2-3
[24] G. W. P. Hadi and D. C. Lantu, “Strategic planning for drone company in Indonesia (Case: PT Terra Drone Indonesia),” *International Journal of Current Science Research and Review*, vol. 6, no. 6, pp. 3212–3222, Jun. 2023. doi: 10.47191/ijcsrr/V6-i6-15
[25] M. Kovacova, G. Di Gravio, and R. Patriarca, “Unmanned aerial systems: Status and forthcoming challenges for safety risk management,” *Transportation Research Procedia*, vol. 65, pp. 329–338, 2022. doi: 10.1016/j.trpro.2022.11.037
[26] A. R. Hall and C. J. Coyne, “The political economy of drones,” *Defence and Peace Economics*, vol. 25, no. 5, pp. 445–460, 2014. doi: 10.1080/10242694.2013.833369
[27] I. Y. Arini, K. Komarudin, and A. Hidayatno, “Exploring the policy structure of aircraft industry development in Indonesia: A conceptual model.” Accessed: Feb. 8, 2024. [Online]. Available: https://www.researchgate.net/publication/342352003
[28] P. Cohn, A. Green, M. Langstaff, and M. Roller, “Commercial drones are here: The future of unmanned aerial systems.” Accessed: Feb. 8, 2024. [Online]. Available: https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/commercial-drones-are-here-the-future-of-unmanned-aerial-systems#/
[29] R. L. Finn and D. Wright, “Privacy, data protection and ethics for civil drone practice: A survey of industry, regulators and civil society organisations,” *Computer Law and Security Review*, vol. 32, no. 4, pp. 577–586, Aug. 2016. doi: 10.1016/j.clsr.2016.05.010
[30] B. Rao, A. G. Gopi, and R. Maione, “The societal impact of commercial drones,” *Technology in Society*, vol. 45, pp. 83–90, May 2016. doi: 10.1016/j.techsoc.2016.02.009
[31] E. Esposito and L. Raffa, “Global reorganisation in a high-technology industry: The aircraft industry,” *International Journal of Globalisation and Small Business*, vol. 2, no. 2, pp. 166–184, 2007. doi: 10.1504/IJGSB.2007.015480
[32] N. A. Khofiyah, W. Sutopo, and M. Hisjam, “A framework for developing technopreneurship and innovation system: A comparative study of agricultural drone technology development in Indonesia,” *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management*, Aug. 2020, pp. 1251–1262. Available: https://index.ieomsociety.org/index.cfm/article/view/ID/4420
[33] N. A. Khofiyah, W. Sutopo, and R. Ardiansyah, “Global business strategy for commercializing a technology of drone: A lesson learned from DJI drones and parrot drones,” *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management*, Aug. 2020, pp. 1014–1025. Available: https://index.ieomsociety.org/index.cfm/article/view/ID/4398
[34] S. M. Mcgovern, “UAS flight test for safety and for efficiency,” *Integrated Communications Navigation and Surveillance (ICNS) Conference*, 2017, pp. 6A2-1-6A2-12. doi: 10.1109/ICNSURV.2017.8011937
[35] Z. Sándor and M. Pusztai, “Certification of unmanned aircraft systems — from product safety to type certificate — a review about the operation of the EU safeguard processes,” *Acta Technica Jaurinensis*, vol. 15, no. 1, pp. 36–46, Oct. 2021. doi: 10.14513/actatechjaur.00642
[36] M. A. Plucken, “The regulatory approach of ICAO, the United States and Canada to civil unmanned aircraft systems, in particular to certification and licensing,” Master’s thesis, McGill University, Montreal, Canada, 2012. Accessed: Feb. 10, 2024. [Online]. Available: https://escholarship.mcgill.ca/concern/theses/3f462945s
[37] A. Gilli and M. Gilli, “The diffusion of drone warfare? Industrial, organizational, and infrastructural constraints,” *Security Studies*, vol. 25, no. 1, pp. 50–84, Jan. 2016. doi: 10.1080/09636412.2016.1134189
[38] M. Coccia, “Sources of technological innovation: Radical and incremental innovation problem-driven to support competitive advantage of firms,” *Technology Analysis & Strategic Management*, vol. 29, no. 9, pp. 1048–1061, Oct. 2017. doi: 10.1080/09537325.2016.1268682
[39] S. Magistretti and C. Dell’Era, “Unveiling opportunities afforded by emerging technologies: Evidences from the drone industry,” *Technology Analysis & Strategic Management*, vol. 31, no. 5, pp. 606–623, May 2019. doi: 10.1080/09537325.2018.1538497
[40] J. Paasi, H. Wiman, T. Apilo, and K. Valkokari, “Modeling the dynamics of innovation ecosystems,” *International Journal of Innovation Studies*, vol. 7, no. 2, pp. 142–158, Jun. 2023. doi: 10.1016/j.ijis.2022.12.002
[41] A. D. Setiawan, T. N. Zahari, K. Anderson, A. O. Moeis, and A. Hidayatno, "Examining the effectiveness of policies for developing battery swapping service industry," *Energy Reports*, vol. 9, pp. 4682-4700, Dec. 2023. doi: 10.1016/j.egyr.2023.03.121

[42] A. Subroto, "Using system dynamics approach to support sustainable growth number of small and medium enterprises in Indonesia: Some policies consideration," *SSRN Electronic Journal*, Feb. 2012. doi: 10.2139/ssrn.1992760

[43] A. Hidayatno, A. D. Setiawan, I. M. W. Supartha, A. O. Moeis, I. Rahman, and E. Widiono, "Investigating policies on improving household rooftop photovoltaics adoption in Indonesia," *Renewable Energy*, vol. 156, pp. 731–742, Aug. 2020. doi: 10.1016/j.renene.2020.04.106

[44] A. D. Setiawan, T. N. Zahari, F. J. Purba, A. O. Moeis, and A. Hidayatno, "Investigating policies on increasing the adoption of electric vehicles in Indonesia," *Journal of Cleaner Production*, vol. 380, 135097, Dec. 2022. doi: 10.1016/j.jclepro.2022.135097

[45] A. D. Setiawan, A. Sutrisno, and R. Singh, "Responsible innovation in practice with system dynamics modelling: The case of energy technology adoption," *International Journal of Innovation and Sustainable Development*, vol. 12, no. 4, pp. 387-420, 2018. doi: 10.1504/IJISD.2018.095048

[46] B. Enserink *et al.*, *Policy analysis of multi-actor systems*, 2nd ed. Den Haag: Eleven, 2022.

[47] J. Sterman, "All models are wrong: Reflections on becoming a systems scientist," *System Dynamics Review*, vol. 18, no. 4, pp. 501–531, Dec. 2002. doi: 10.1002/sdr.261

[48] W. A. H. Thissen, "Issue formulation in a multi-actor context: A five-step approach." Accessed: Feb. 8, 2024. [Online]. Available: https://www.researchgate.net/publication/3875971_Issue_formulation_in_a_multi-actor_context_a_five-step_approach

[49] Badan Riset dan Inovasi Nasional, "Penguasaan teknologi kunci PUNA, Kepala BRIN: Butuh kolaborasi lintas OR," Badan Riset dan Inovasi Nasional, Aug. 31, 2022. Accessed: Feb. 21, 2024. [Online]. Available: https://www.brin.go.id/news/110339/penguasaan-teknologi-kunci-puna-kepala-brin-butuh-kolaborasi-lintas-or

[50] E. Dourado and S. Hammond, "Do consumer drones endanger the national airspace? Evidence from wildlife strike data," Mercatus Center, George Mason University. Accessed: Feb. 8, 2024. [Online]. Available: https://www.mercatus.org/students/research/policy-briefs/do-consumer-drones-endanger-national-airspace-evidence-wildlife

[51] Irwanto and Meilani, "Comparative study of tax incentives in Indonesia, Malaysia, and the United States of America to support research and development," *Journal of Accounting & Management Innovation*, vol. 6, no. 1, pp. 182–206, 2022. doi: 10.19166/jam.v6i2.538

[52] Yubiwini and A. Patunru, "Trade and tax evasion in Indonesia," *World Customs Journal*, vol. 12, no. 2, pp. 107–120, 2018. Available: https://www.researchgate.net/publication/333043795_Trade_and_tax_evasion_in_Indonesia

[53] D. H. Kim, *Systems archetypes I: Diagnosing systemic issues and designing high-leverage interventions*. Waltham: Pegasus Communications, 2000.

[54] M. Ghasri and M. Maghrebi, "Factors affecting unmanned aerial vehicles' safety: A post-occurrence exploratory data analysis of drones' accidents and incidents in Australia," *Safety Science*, vol. 139, 105273, Jul. 2021. doi: 10.1016/j.ssci.2021.105273

[55] K. H. Terkildsen and K. Jensen, "Towards a tool for assessing UAS compliance with the JARUS SORA guidelines," *2019 International Conference on Unmanned Aircraft Systems (ICUAS)*, Jun. 2019, pp. 460–466. doi: 10.1109/ICUAS.2019.8798236

[56] X. He, J. Li, and R. Zhu, "The study of company competitive strategy under new manufacturing industry — Taking DJI as an example," *International Conference on Economic Administration and Information Systems (EAIS 2022)*, 2022, pp. 191–198. doi: 10.23977/EAIS2022.023

[57] R. A. Nugraha, D. Jeyakodi, and T. Mahem, "Urgency for legal framework on drones: Lessons for Indonesia, India, and Thailand," *Indonesia Law Review*, vol. 6, no. 2, pp. 137-157, Aug. 2016. doi: 10.15742/ilrev.v6n2.229

[58] S. Çıkmak, G. Kırbaç, and B. Kesici, "Analyzing the challenges to adoption of drones in the logistics sector using the best-worst method," *Business and Economics Research Journal*, vol. 14, no. 2, pp. 227-242, Apr. 2023. doi: 10.20409/berj.2023.413

[59] Association for Uncrewed Vehicle Systems International, "AUVSI partnership for drone competitiveness," *AUVSI White Paper*. Accessed: Feb. 10, 2024. [Online]. Available: https://www.auvsi.org/sites/default/files/AUVSI-Partnership-for-Drone-Competitiveness-White-Paper.pdf

[60] C. Syahlavida, Y. Ali, H. Saragih, and G. R. Deksino, "Manajemen produksi pesawat terbang tanpa awak (unmanned aerial vehicles/uav) dalam mendukung kemandirian industri pertahanan (studi kasus PT. Uavindo Nusantara dan PT. Famindo Inovasi Teknologi)," *Jurnal Manajemen Pertahanan*, vol. 6, no. 2, pp. 38–60, 2020

[61] R. M. Askar Pejuang, "Maximizing Indonesia's drone potential for military and civil purpose," *CSIS Notes, May 18, 2022*. Accessed: Feb. 21, 2024. [Online]. Available: https://blog.csis.or.id/maximizing-indonesias-drone-potential-for-military-and-civil-purpose-875db970907a

[62] N. Syaifudin, A. Sutrisno, and A. D. Setiawan, "The Impact of Fiscal Transfer on Energy Efficiency in Indonesia," Energy Procedia, vol. 65, no. 0, pp. 239-247, 2015. doi:10.1016/j.egypro.2015.01.037