System Dynamics Model of Research Performance Among Academic Staff

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***Abstract*—The link of research and innovation in higher education are continually receiving worldwide priority attention. Hence, Malaysia has taken its move to enhance public universities as a centre of excellence by introducing the status of Research University (RU). To inspire all universities towards becoming a research university, The Ministry of Higher Education (MoHE) had revised an assessment called Malaysian Research Assessment Instrument (MyRA) to evaluate the performance of existence RUs and other potential higher education institutions. The available spreadsheet tool to access MyRA performance is inadequate to support strategic planning. Since, higher education management is a complex system, in which components and their interactions are ever changing over time, there is a need to for an efficient approach to investigate system behaviour and devise research management policies for the benefit of the institution itself and the higher education system. In this paper, we proposed a system dynamics simulation model to evaluate the impact of research policies for obtaining the highest performance in MyRA assessment. Causal loop diagram and stock and flow diagram are developed to investigate the relationship of various elements in the research management, their inter-relationship that link together and their evolution of behaviour over time is presented. Finding from this research will be helpful to assist the university management to better understand the cause and effect of research activity on the MyRA performance.**

***Index Terms*—Higher Education; System Dynamics; Simulation; Assessment.**

I. INTRODUCTION

Vision 2020 embarked Malaysia towards becoming the first full fledge developed nation amongst developing countries. One of its strategy in achieving higher personal income and better quality of life is by strengthening the higher education industry to inject more new income and generate economic resources. The nexus of research and innovation in higher education are continually receiving worldwide priority attention, hence this area would likely be invested in the national plan to make sure that higher education in Malaysia is on par with other developed nation.

The key line ministries which authorize in managing research and innovation in Malaysia is The Ministry of Higher Education (MoHE). The main thrust of MoHE is to enhance research and innovation by producing a critical research mass of researchers, developing a knowledge corpus and supplying sufficient research and development (R&D) resources [1] empowered under the National Higher Education Strategic Plan for 2007-2020 (NHESP). In succeeding the plan, Malaysia has taken its move to enhance public universities as a centre of excellence by introducing the status of Research University (RU) that drives R&D, commercialization and production of postgraduates. MoHE aspires to have six RU by the year 2020, however, only five public universities had successfully entitled the status Research University up to now [2].

Generally, RU functions as a hub that focuses on research activities and creation of advanced knowledge based on R&D [1]. Thus, in order to make sure that the research university will continue succeeding the government's vision, MoHE introduced a special fund for Research University allocating over RM100 million in 2008. To inspire all universities towards becoming a research university, MoHE had revised an assessment called Malaysian Research Assessment Instrument (MyRA) to evaluate the performance of existence RUs, as well as other higher education institutions potentially to be awarded the title. MyRA is underpinned by a number of important key areas measurement. The measurement consists of eight sections (A-H) which are: general information, quantity and quality of researchers, quantity and quality of research, the quantity of postgraduates, innovations and intellectual property, professional services and gifts, networking and linkages, and services.

All universities are required to attempt MyRA self-assessment using the web-based system that takes input data of each criterion and computes the marks obtained, which shows an indicator of RU qualification. MyRA assessment is tailored to foster the excellence of research and development in higher education which requires strategic planning to improve the performance by ensuring the best decision is made. In strategic planning, it is important to have a comprehensive understanding of the factors and its interlinked affecting each key area measurement in order to design relevant policy to improve its performance. However, the web-based system only allows university management to keep track on values and the calculation. Generally, it is a static model that does not attribute to strategic planning or give information on the relationship between variables [3]. Due to this limitation, numerous research adopted system dynamics (SD) to support the decision-making in higher education management. In stark contrast, SD is capable to capture the dynamic, complexity and non-linearity behaviour of a system and supports strategic planning [4]. Therefore, the focus of this paper is to develop causal loop and stock and flow diagrams to investigate the relationships between various elements in the research management and their interrelationships that generate the behaviour over time. Then, the effect of research activities on MyRA performance can be analyzed.

The rest of this paper is organized as follows: The first section reviews the literature on the application of system dynamics in education management and example of interactive software in education management. The next section presents the methodology of system dynamics and its

modeling process. In the following section, the causal loop diagram of the proposed framework is presented to explain the causal relationship in the higher education management research model, followed by conclusion in the final chapter.

II. Literature Review on The Related Works

Until recently, many researchers have shown interest in explaining different higher education aspects using system dynamics. As earlier literature confirm that higher education issues are applicable with system dynamics, given its complex nature that is dynamic, involve the notion of feedback, delays and non-linearity system [5,6]. An archetype of feedback, delays and non-linearity in higher education is the research publication process, where research manuscript goes through a series of process: (1) received paper, (2) revised paper, (3) accepted paper and (4) available online, likewise, publication citation may take more time for the paper being known among researchers before being cited.

The most extensive review on the use of system dynamics in education management was done by Kennedy where he has put much effort in compiling and comprehensively reviewed series of literature in the domain. His broad review had recognized six themes related to educational policy issues namely (i) external force and legislation, (ii) corporate governance, (iii) planning, resourcing and budgeting, (iv) human resource management dilemmas, (v) teaching quality, (vi) teaching practice, (vii) micro worlds and (viii) enrolment demand. His work has been referenced by many other researchers in the domain that imitate existing model structure in the literature by deploying other techniques and styles based on the six topics mentioned in his paper, as well as serving as a source for future research and hypotheses [6]

Many researchers had contributed to the growing literature in the theme planning, resourcing and budgeting. A few researchers had studied the first subject of funding allocation, that explores the interaction between funding allocation and its distribution on publication, citation and postgraduate students. A notable study by Galbraith had applied system dynamics to investigate the effects of various incentive schemes in higher education on the basis of improving research productivity [7]. His compelling finding was that incentive schemes are necessary for increasing the unit research productivity. He explains that in absence of research fund growth, every additional effort in increasing publication, grant and thesis student would mean depreciating the benefits gain for each additional unit compared to the previous one. Nevertheless, his work was criticized by [6] because he did not affiliated with any university's management in Australia which results in lacking model structure ownership. Other studies worth mentioning is the work of [8] and [9] which approved the findings by [7]. [8] claim that stagnation in government research funding in long-term could bring unintended effects such as hampering of research discoveries and halt the research workforce development as more researchers find it unattractive to stay in the research career. The latter expanded the model by enumerating the causal link between public funding, academic activities, institution strategic goal and the performance output. Similarly, their outputs confirm that there exists a positive feedback loop, where research funding influence human capital capacity which in turn influence the research output.

Another facet of higher education research issues is the dynamic of research performance that emphasize on the quality of the publication and its citations. Researchers contended that the dynamic of academic publication and citation changes the researcher behaviour in making sure they fulfil the institution's key performance index requirement [10,11]. It is argued that the pressure exerted on the researcher to increase the number of publication would, in turn, produce an inferior quality of the publication, although the number of publication increases, nevertheless the number of citations per publication decreases due to its low quality. [10] developed a system dynamics model to explore the change in researcher's behaviour when dealing with pressure to increase research performance. The key finding in the research is that when researchers are a burden to increase their publication, they tend to publish by numbers rather than quality. The decisive variables to overwhelm publication pressure is by increasing academic staff skill level in research and increase citation pressure rather than merely increasing publication pressure. A similar study by [11] extended the earlier study by [10] that proportionate the publication into three quality ranking namely type A (finest quality), type B (best quality) and type C (low quality). The result of their simulation suggested that to increase the type A publication, researchers have to dedicate much time in doing research and are given the option to exclude in other academic activities such as teaching and administration.

Academic staff plays an important role in ensuring research performance and reputation of an institution. The development of building skills and expertise in research is a challenge where management needs to plan for effective strategies to manage scarce resources available. Moreover, most of the funding schemes enacted by MoHE are based on research performance. MoHe has confidence that research universities are among producers in advancing growing knowledge which is essential for national development [1]. Among researcher which has simulated the dynamic of academic workforce career are the work by [9,12,13]. The fundamental idea of academic workforce planning was presented by [4] in his book Business Dynamics, where he modeled the academic staff promotion structure at Massachusetts Institute of Technology (MIT). [4] points out that the promotion rate will influence the attractiveness of young talent to stay in the organization, else they will leave, as more outside opportunities waiting for them, eventually in long run affects the quality of academic staff performance. A similar study that applies the idea is the work by [12] that employed system dynamics to analyze the effect of government funding regimes on academic workforce development and research output in Dutch Universities. Their findings highlight that increasing the retirement age cap for academic staff would affect the temporary researcher workforce as there are fewer chances to promote temporary researcher to a permanent position. Eventually, temporary researcher finds it less attractive engaging in a research career, which in the model, shown by the high inflow and outflow of academic staff stock. In long run, if this circumstance continues, it might affect research quality, as new temporary researcher entering the workforce needs more time to adapt and gain skill and experience in research, they are more valuable if they stay in the profession for a longer time. Besides that, they also explained the behaviour of the researcher when the universities emphasize on competitive funding scheme activity when more time is spent preparing a proposal in gaining the fund, this will lead to a loss of research productivity, as researchers prefer to spend time on

writing research proposal instead of carrying out research activity.

Although the simulation model discusses earlier supports strategic decision-making process in higher education management, it is not useful without the participation of stakeholders. To engage stakeholders in decision-making, a dynamic model built should deploy into interactive software for the ease of understanding and usability. [14] had developed an interactive dynamic simulation model for university management called "UNIGAME". The interactive game allows a player of all management level to decide on which strategies they desired to produce numerous performance measures of the university. The issues that the players need to tackle include growing student-faculty ratios, poor teaching quality, and low research productivity. Similarly, virtual university game "Virtual U" (VU) pioneered by Dr. William F. Massy was developed in a highly user-friendly manner to help real administrators, deans, and university funder to decide on the best strategies ensuring best performance is achieved within a period of time [15]. The simulation university game was designed to promote awareness on managing the scarce resources available in a university environment. [9] advocates that system dynamics is a useful university management tool because it allows involvement of decision maker throughout the modeling process.

From the literature review, most of the case study applied in system dynamics depicts the applicability of the method in complying the long-term analysis of the university management which predicts the system's behaviour over time. Moreover, there exists a consensus among researchers regarding the relationship between various entities of research but may differ in terms of weight assign to the parameter. Apart from that, the dynamic complexity of higher education management deals with the abundance of variables, interacting among them that intertwine and influence one another throughout time, satisfies what system dynamics method offers. It helps managers to understand the impact of their decision in long run. Moreover, the sensitivity analysis allows the effects of delay in higher education management planning to be captured, gaining an understanding of the non-intuitive behaviour of the system when certain decisions are altered. The web-based system is not adequate for strategic planning as it only tackles static issues such as per year basis performance, but does not capture the dynamic performance over time) [16]. We contend that the application of system dynamics is suitable as a proxy to model higher education management as it allows a better understanding of the system structure, foresee its behaviour over time and most importantly involves decision maker in the modeling process to ensure that the simulation model maps the actual system. The summary of the discussed literature on education management using system dynamics is presented in Table 1.

III. METHODOLOGY

System dynamics (SD) is methodology firstly introduced by Professor JW Forrester in the mid-1950's at the Massachusetts Institute Technology (MIT) [17]. It is a computer simulation approach to understand the changes in the behaviour of the complex problem over time. In SD, both of quantitative and qualitative analysis was used as shown in Figure 1 that aims to enhance the understanding of the behaviour of the system. In this study, the qualitative analysis involved mapping process meanwhile quantitative analysis involved with model development using Vensim™ software [4]. Basically, SD explains that the non-intuitive or counterintuitive behaviour of the system lies not merely to the variable of the system but to the structure in which they interact to form certain behaviour. The structure of the system that unfolds the dynamic concept of feedback, time delays and non-linearity makes them a complex system. Thus, SD aims to gain an understanding of the causal relationship and feedback loop presents in the complex system [18].

In this research, the modeling process based on SD methodology involves five key steps as presented in Figure 1. The steps are problem articulation, formulation of dynamic hypotheses, formulation of the dynamic simulation model, model testing, and policy design and evaluation.

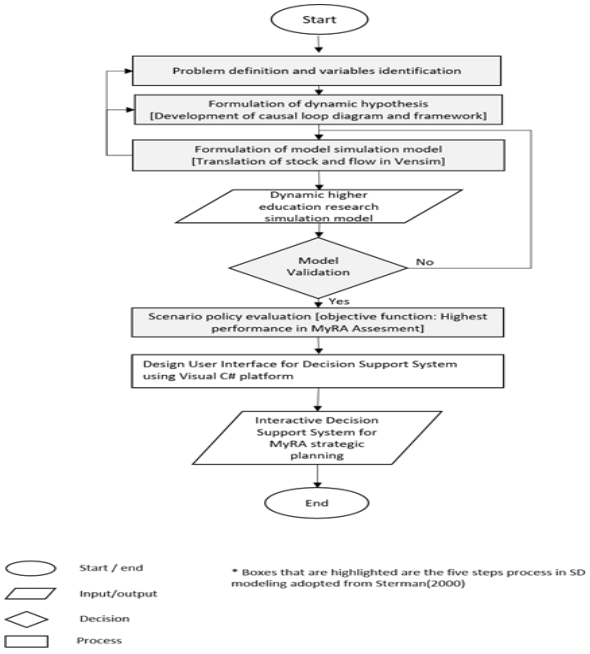

Figure 1: System dynamics modeling process

Referring to Figure 1, the second stage involved with the development of a dynamic hypothesis. The dynamic hypothesis is an intuitive explanation concerning the causal relationships that produce observed system behaviour. It is generally believed by system dynamists that a dynamic hypothesis is necessary before any modeling efforts can begin. Figure 2 presents a proposed a framework that sets the boundary of the research.

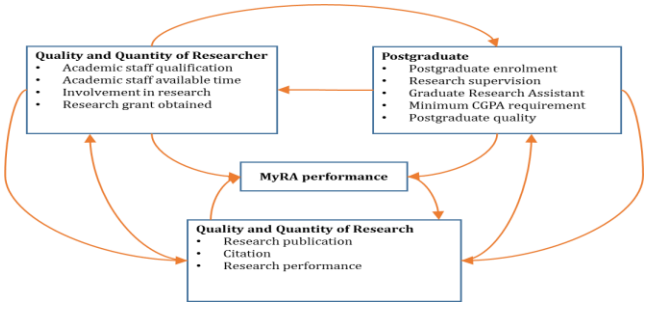

Figure 2: System dynamics modeling process

Table 1
Summary of literature on education management using system dynamics

Authors	Country	Objective	Findings
Barlas & Diker (1996)	Bogazici, university Turkey	Developed an interactive simulation model on which various problem involved in managing the academic aspect of the university can be analyzed and certain policies for overcoming these problems can be tested.	The interactive game is useful to support strategic decision in education management.
Galbraith (1998)	Australia	Address issues that arise imperatives when the desires to maintain or increase staff establishment and research performance intersect with imperatives to balance budgets in a climate intra-institution.	Incentive schemes are necessary for research productivity.
Kennedy (1998)	South Bank London University	Developed SD model to assist in policy analysis with respect to quality issues in education management that includes administration, staff morale and motivation, and research.	A SD model allows experimentation with different scenario generating the behaviour of the system over time.
Vahdatzad & Mojtahedzadeh (2000)	Yazd University, Iran	Addressed the growing number of students, faculty members and university resources.	Established research centre with adequate resources of facilities and human capital. University is given autonomous to plan on courses and research activities utilizing scarce resources.
Kennedy (2000, 2002)	Review paper	To facilitate and structure debate on the use of system dynamics in Education Management.	Review of previous literature in education management.
Oyo, William & Barendsen (20080	Uganda	Investigate the dynamic on part-time teaching, staff to student ratios, staff development, research productivity, and hence the perceived quality using system dynamics	Higher education funding on staff quality affects research performance and basic operational costs provisions. Governments and donor institutions must demonstrate willingness to invest in research
Kucuk, Giler & Eskici (2008)	Bogazici University, Turkey	Developed a SD model to examine change in researcher's behaviour when an increase in pressure to improve research performance.	Publication pressure reduces the quality of publication and citation received. Citation pressure, together with a skill level of the researcher, increase the quality of publication, citation and reputation of the institution.
Dahlan & Yahya (2010)	Malaysia University of Science & (MUST)	Determine factors that form the basis of a decision support system for meeting the supply and demand of academic program, which contributes to efficient resource management using SD.	Developed a framework on the basis of university management resources and its relationship.
Onsel & Barlas (2011)	Bogazici University, Turkey	Developed a dynamic model to analyze changes in publication practices of researcher towards improving the performance measurement.	Devote more time to research, increases research productivity. Increasing skill level of faculty members increases publication and citation performance.
Kersbergen, Daelan, Meza & Horlings (2015)	Dutch	Developed a model that describes the influence of funding regimes and career policies on the workforce development and research output over time.	Increased focus on government funding would lead to a larger workforce, but not to a research output. Increasing the retirement age gap of academic staff would destabilize the temporary researcher workforce.
Mekulov, Nezamoddini & Sabounchi (2015)	United States	Studied the graduate education programs in the US that aim to balance between the increase in enrollment without losing the quality and affordability of education.	Identified feedback loops connecting enrolment, acceptance rate and the quality of new applicants of a student with ranking and reputation, as the available intervention is to control the admission policy.

The next stage is formulating a causal loop diagram (CLD). CLD is a causal diagram that aids in visualizing how different variables in a system are interrelated through the cause and effect relationship between elements that drives the system behaviour over time. Constructing CLD will form a feedback loop, which is a closed chain relationship which helps identified how elements affect each other [18]. CLD connect the causal variables by arrows to show there exist a relationship, while the polarity sign shows the direction of influence. Positive polarity depicts a positive direction relationship: where an increase in a former element increases the subsequent element; while negative shows polarity shows the opposite direction of influence. Figure 3 shows an example of a positive relationship between cause and effect.

Figure 3: Example of positive polarity cause and effect

The positive polarity (+ve) indicates a positive relationship between the factors and vice versa. For instance, an increase in incentives scheme awarded by universities will increase the motivation of researchers to spend more time in the writing process. A positive loop depicts the growth of the system behaviour over time, whereas a negative loop counteracts any changes in the system [4]. On the other hand, negative polarity (-ve) indicates a negative relationships explanation. The next section will provide a CLD that explains the higher education research management for improving the understanding of each element and accentuating the system's behaviour.

IV. Causal Loop Diagram Of Research Activities

Basically, the overall model is organized into three sections; quality and quantity of researcher, quantity and quality of research, and quantity of postgraduates pertaining cause and effect relationship between the variables. The CLD model developed is based on the university's facilities and research practice in management university of Universiti Utara Malaysia.

The overview CLD of the system that shows the feedback caused by the relationship of the three sections mentioned earlier is presented in Figure 4 below. The diagram was developed by citing the works of previous authors on the various structures that have been linked and assess the impact of research quality; and by brainstorming among academic experts in the area of higher education research management.

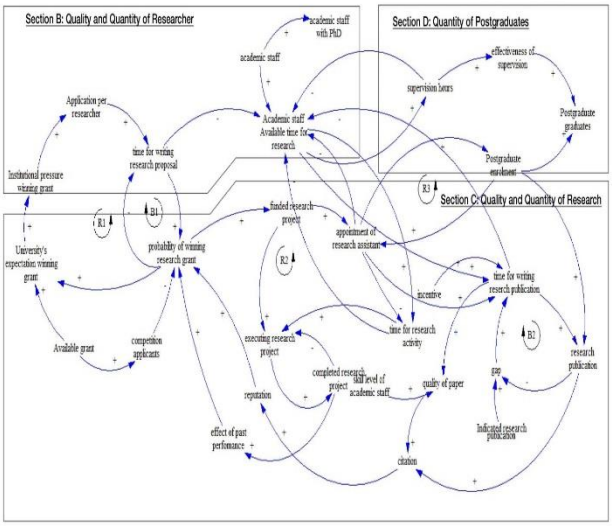

Figure 4: Causal loop diagram on the cause and effect of the research productivity

The explanations for each loop section are as follows:

A. Loop 1: Research Proposal Activity

Loop R1 is a reinforcing force which shows the complexity of the system when researchers respond to the changes in their work environment. Available fund from the government increases the university's expectation of winning the grant to fund their research, thus researcher needs to spend time writing a research proposal for submission. As researchers invest more time in writing proposal, it increases chances of winning the research grant, consequently increases university's expectation of winning the grant

B. Loop 2: Competition in Research Grant

B1 shows that the government decision in offering not only the public universities but other private higher education institutions will dramatically increase the competition applicants in applying for a research grant. As the number of competition increases, the probability of an institution of winning diminishes, which triggers researcher to spend more time writing a research proposal. Pressure to spend time on writing will deviate researcher time on doing research activity as more time is devoted to writing an outstanding research proposal as shown in Figure 5.

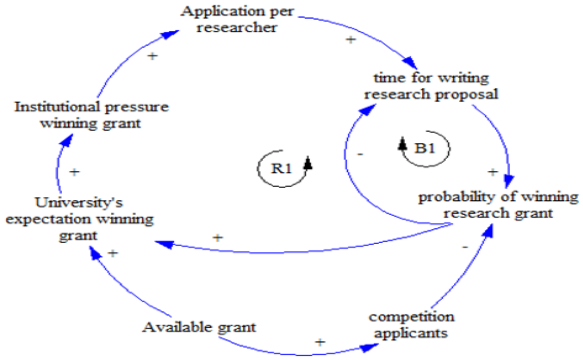

Figure 5: Feedback loop on research writing activity

C. Loop 3: Growth in Publication and Citation

Research findings carried out by researcher needs to be disseminated to inform public on the research work done that contributes to the expansion of existing knowledge. Published research works help to sustain the development of existing knowledge and allow the practitioner to apply the knowledge in solving problems in their work environment [19]. B2 in Figure 5 is a balancing loop explains that researcher spent time in writing publication increases when there is pressure to meet the requirement by the institution of the number of articles they need to publish in a year, the pressure reduces as the gap reduces. Besides that, incentives scheme for publication also exerts pressure in terms of motivation for the researcher to spend time writing research publication which influences the quality of the paper. The combination of spending more time in writing research publication and academic skills contributes to the quality of publication which leads to higher number of citation that the works received over time. Figure 6 shows the growth in publication and citation.

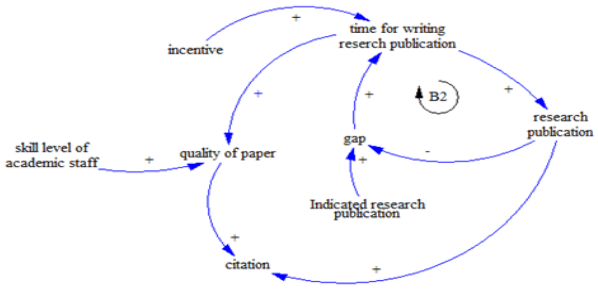

Figure 6: Feedback loop on reputation growth

D. Loop 4: Reputation Growth

Publication and citation is a measure of research productivity and is used in the computation of MyRA

performance. An increase in publication and citation as depicted in Figure 7 will increase the institution reputation. Reputation gain over time will influence increases in the probability of winning research grant in the future as researchers had gained skills and experience from the previous research activity. The loops generate a vicious cycle that depicts a growth behaviour in research performance, given that the writing motivation of researcher, pair with skills and experience will continuously improve.

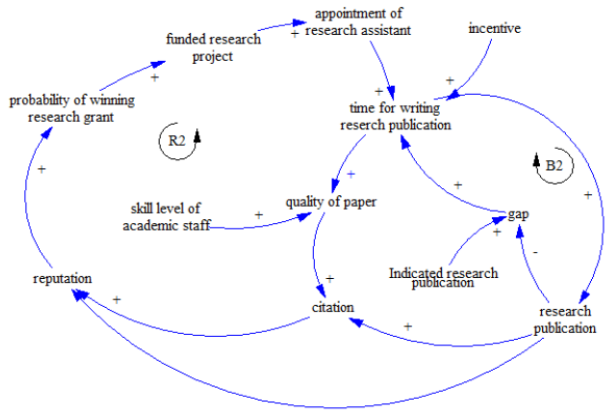

Figure 7: Feedback loop on reputation growth

E. Loop 5: Hiring of Graduate Research Assistant

Research project funded by the government is compulsory to have one postgraduate student as a requirement for project completion. As more research project is being funded, more graduate research assistant can be hired to assist in the completion of research project. The appointment of a research assistant is said to speed the research project completion. Postgraduate candidates that are being hired as a research assistant will be remunerated with the project funding. The scenario is followed by an increasing number of postgraduates as they have a fund available to bear their cost of postgraduate's studies.

In the ongoing simulation model, researchers, refers to the academic staff, as they are the main player in determining the research performance and reputation of an institution. Their staff behaviours' changes in response to any change in the work environment all together give rise to the feedback structure that exists in the system. These insights could be helpful to decision-makers in making more informed and justified decisions.

V. Stock and Flow Diagram Of Research Activities

CLD is the first step in developing a SD model that helps analysts to view the complex system structure qualitatively in terms of cause and effect [20]. While a stock and flow diagram (SFD) is a formal model that enables the quantitative analysis of the system behaviour over time can be analyzed. In SFD, a stock is an accumulation of information over time, while flows are an increase or decrease of the stock known as inflow and outflow [4]. The SFD of the university research management was developed using Vensim DSS 6.2 software. For the purpose of this paper, the model is divided into two subsections model namely academic staff, and research activity. A more detailed explanation is explained below.

A. Academic Staff Model

The SFD of academic staff model is presented in Figure 8 below. The academic staff sector shows the stock of the academic staff which grows by hiring and promotion to the higher academic position, while attrition reduces the stock of academic staff. The hierarchal academic position translates the productivity for each group, where the associate professor and higher are more productive in research work. The academic staff number will contribute to the number of research activity hour that produces output in terms research grant won, research publication, citation and university reputation.

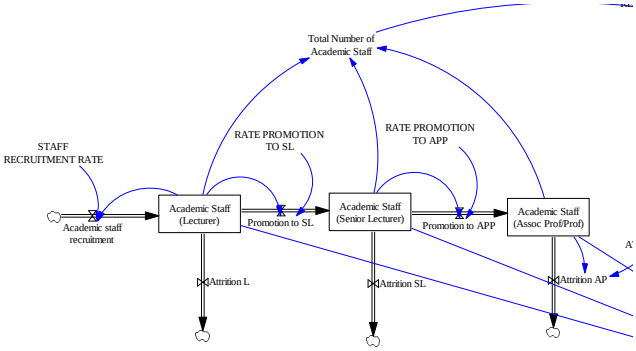

Figure 8: Stock and flow diagram of academic staff model

B. Research Activity Model

The second section is the research activity model. This section emphasizes the relationship between research activity such as research grant and publication as demonstrated in Figure 9 and Figure 10. The total research time is the average time that the academic staff dedicated to research activities. The total research time is the summation of the normal research time and additional research time. The additional research time changes due to the effect of publication pressure to achieve yearly key performance index (KPI) for publication per academic staff per year. The total research time deducted by the time spent preparing for research grant will produce the research hours per researcher which is exclusively the time for researchers to carry out research activity. The time taken for preparing research grant influences the acceptance rate of winning the research grant. As more time is spent writing a research proposal, the higher the acceptance rate of research applied. Nevertheless, too much time taken preparing for research grant will eventually diminish the time researchers spend on research activity.

The research activity hour is the product of the number of academic staff, research hours per researcher and their productivity. The output through spending time on research activities is the research publication which will have an impact on the citation and reputation. The number of research publication is compared with the total indicated publication that the academic staff needs to produce to fulfil their KPI, subsequently, produces publication pressure. As more gap exists between the two numbers, the higher the publication pressure forcing the researcher to produce more publication in a shorter length of time. Consequently, there exist two feedback loops, the first one is that the researcher will tend to spend more time in research activity to increase the number of publication, that is translated through the reserved time per paper. The second feedback loop is that the publication pressure would affect the quality of paper when the time taken for writing a research publication is shorten. Quality is

introduced in the model, to estimate the number of citations the publication received based on the quality of the paper. Quality is also affected by the skill member of researcher measured on a scale of 0 to 1. In the model, the skill level is an exogenous variable that has a positive impact on the quality of the publication and the number of citations received [11].

Furthermore, the output from the research that is the research publication and citation received will have a positive feedback loop between the reputation, citation and acceptance rate of the research grant application as a researcher had gained experience, skills and prominence in the publishing field. In the model, an increase in reputation explains that the researchers have excellent skills in conducting research. The reputation will have important feedback that will increase the number of citations per publication they received.

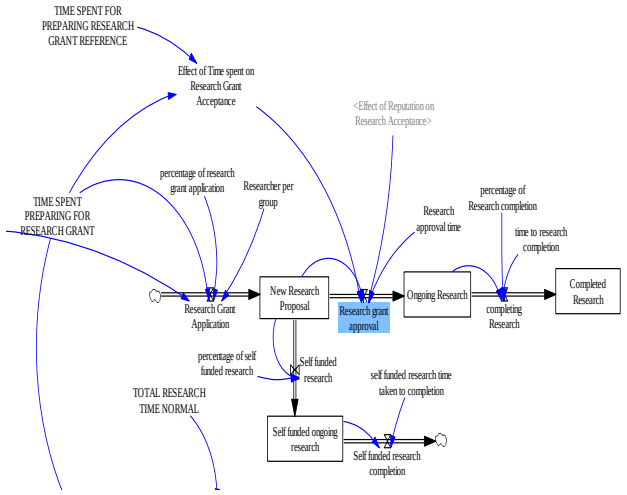

Figure 9: Stock and flow diagram of research activity model (part A)

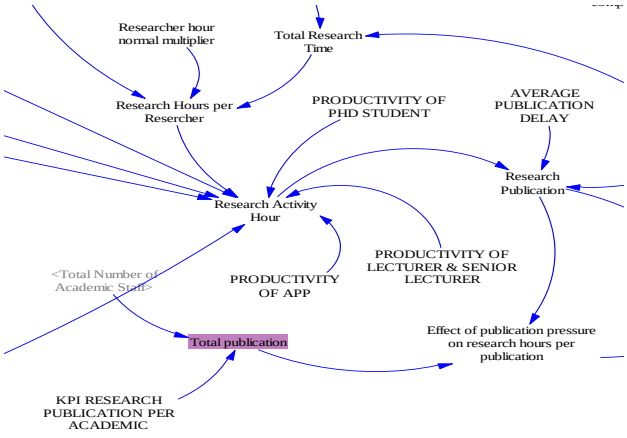

Figure 10: Stock and flow diagram of research activity model (part B)

VI. Results and Analysis

A. Base Run Scenario

The model is simulated to observe the behaviour of the research productivity in terms of research grant application and total publication. The simulation is run for 22 years, from 2008 to 2030. The finding from the base run shows that increase in the number of staff results to the increases in the number of research grant application and total publication as demonstrated in Figure 11.

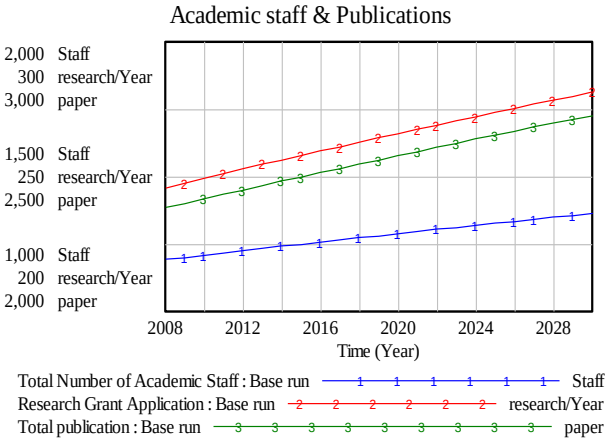

Figure 11: The effect of academic staff on the research activity performance.

B. Intervention Scenario

One of the important criteria for MyRA is the assessment on the research grant and total publication. The experiment called Scenario 1 is the changes made in the number of academic staff compared to base run experiment. A change in the parameter namely STAFF RECRUITMENT RATE is assumed to commence in 2017. This scenario is made up to 50% change for standard comparison. The equation for the changes parameter is shown in Equation (1). In this experiment, other variables are maintained in the base run model.

STAFF RECRUITE\MENT RATE = IF THEN ELSE (Time<=POLICY YEAR, 0.013, 0.0065) (1)

The results of the run model are presented in Figure 12-Figure 14. Based on the intervention experiment (Scenario 1), the result shows that reduce the number of recruitment staff starting from 2017 effect on the decreasing trend in the total number of staffs in UUM start from 2017 to 2030. This reduction results to the declining trend in the number of research grant applied by the lecturer especially from senior lecturer and professor. Finally, this will affect on the total publication produced by the UUM staff and cause to the unachievable KPI target set by the university.

VII. Conclusion & Future Work

This paper describes the work of developing a CLD and SFD for strategic planning in higher education management. Unlike the web-based system that hides the relationship on how elements interrelate and interact, thus, the system does not support strategic planning process towards MyRA assessment. In contrast, the developed CLD and SFD diagram in this research present the dynamic relationship between the entities that define the measurement performance and will be useful to assist the UUM management to better understand the cause and effect of research activities on the MyRA performance.

The future work of this study is to develop a model section of the postgraduate student which is one of the important criteria that have an impact on the university's policies related to MyRA assessment. The SD model developed will focus on the quantifiable criteria on research performance which will be integrated with the formulas in MyRA assessment in order

to achieve UUM KPI. Then, an interactive decision support system will be developed to obtain the highest performance in MyRA performance.

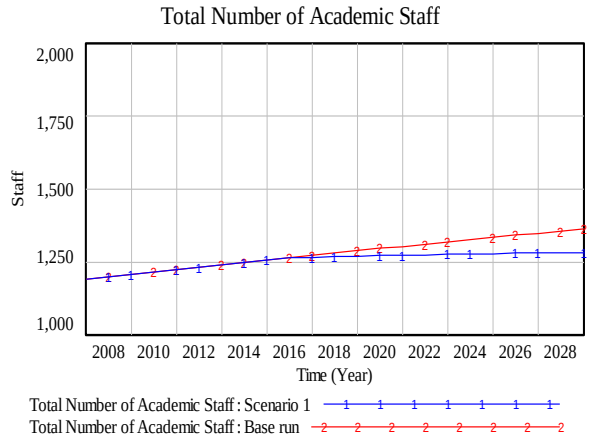

Figure 12: Comparison of total number of academic staff before and after intervention scenario

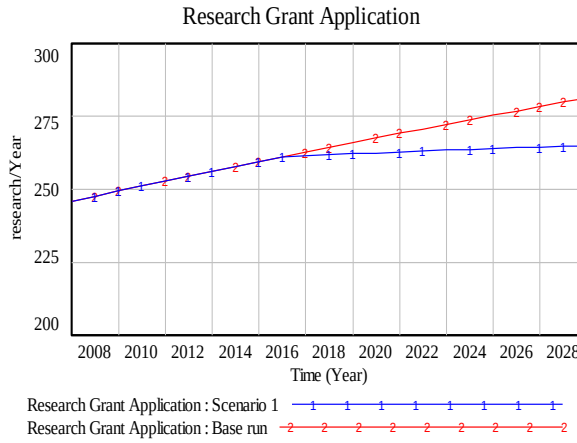

Figure 13: The effect of reducing in number of staff on the research grant application

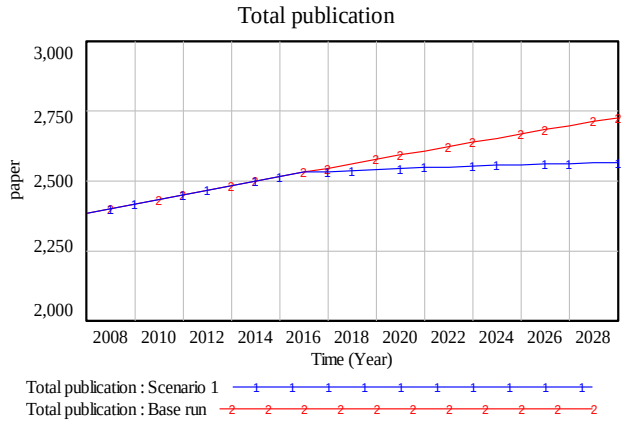

Figure 14: The effect of reducing in number of staff on the total publication

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REFERENCES

[1] MoHE, The National Higher Education Strategic Plan: Laying The Foundation Beyond 2020. Kuala Lumpur, Ministry of Higher Education, 2007.

[2] Ministry of Education *Malaysia education blueprint (Higher Education) 2015–2025*. Putrajaya: Ministry of Education Malaysia, 2015.

[3] M. Kennedy, and C. Clare, C. "Some issues in building system dynamics model for improving the resource management process in higher education (Published Conference Proceedings style)," in *Proc. of. the 17th International System Dynamics Conferenc*e, Wellington, New Zealand, 1999/

[4] J. Sterman, *Business Dynamics: Systems Thinking and Modeling for A Complex World.* Boston: Irwin/McGraw-Hill, 2000.

[5] M. Kennedy, "Towards a taxonomy of system dynamics models of higher education (Published Conference Proceedings style)," in *Proc. of the 18th International Conference of the System Dynamics Society*, Bergen, Norway, 2000

[6] M. Kennedy, " An extended taxonomy of system dynamics models of higher education (Published Conference Proceedings style)," in *Proc. of the 20th System Dynamics Conference*, Palermo, Italy, 2002

[7] P.L. Galbraith, "System dynamics and university management," *System Dynamics Review*, vol. 10, no. 2, pp 69-84, 1998.

[8] G. M. Diaz, N.V. Ghaffarzadegan, and R. Larson, *Unintended effects of changes in NIH appropriations: Challenges for biomedical research workforce development*, Massachusetts Institute of Technology, 2012.

[9] B. Oyo, D. Williams, and E. Barendsen, "A system dynamics tool for higher education funding and quality policy analysis (Published Conference Proceedings style)," in *Proc. of the 26th International Conference of the System Dynamics Society*, Athens, Greece, 2008, pp. 1-29.

[10] B. Küçük,, N. Güler, and B. Eskici, B. "A dynamic simulation model of academic publications and citations (Published Conference Proceedings style)," in *Proc. of the 26th International Conference of the System Dynamics Society*, Athens, Greece, 2008, pp. 1-23.

[11] N. Onsel, and Y. Barlas, Y. "Modeling the dynamics of academic publications and citations (Published Conference Proceedings style)," in Proc. of the 29th International Conference of the System Dynamics Society, Washington, DC, 2011.

[12] R.J.V. Kersbergen, C.E.V. Daalen, C.M.C. Meze, and E. Horlings, "The impact of career and funding policies on the academic workforce in the Netherlands: A system dynamics based promotion chain study (Published Conference Proceedings style)," in *Proc. of the 34th International Conference of the System Dynamics Soc*iety, Delft, Netherlands, 2016, pp. 1-15.

[13] Y. Barlas, and G.V. Diker, "Decision support for strategic university management: A dynamic interactive game (Published Conference Proceedings style)," in *Proc. of the 14th System Dynamics Conference, Boston*, USA, 1996, pp.47-50.

[14] Y. Barlas, and V.G. Diker, "A dynamic simulation game (UNIGAME) for strategic university managements," *Simulation & Gaming*, vol. 31, no. 3, 2000.

[15] C. Aldrich, *Learning Online with Games, Simulations, and Virtual Worlds: Strategies for Online Instruction* (Book style). San Franciso, CA: Jossey-Bass, 2005.

[16] M. Kennedy "A pilot system dynamics model to capture and monitor quality issues in higher education institutions experiences gained (Published Conference Proceedings style)," *in Proc. of the 16th System Dynamics Conferenc*e, Quebec City, Canada, 1998, pp. 1-7.

[17] J.W. Forrester, *Industrial Dynamics* (Book style). Productivity Press, Cambridge, MA: USA, 1961.

[18] J.M. García, *Theory and Practical Exercises of System Dynamics* (Book style). Barcelona: Juan Martín García, 2006

[19] M. Winston, and J.F. William, "XXX", *Journal of Education For Library and Information Science*, vol. 44, no. ¾ (Sumemr/Fall), pp. 221-234, 2003.

[20] H. Sapiri, J. Zulkepli, N, Ahmad, N.Z. Abidin, and N.N. Hawari, *Introduction to System Dynamics Modelling and Vensim Software*. UUM Sintok: UUM Press, 2017.