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Full Length Research Paper

System dynamics approach in analyzing impact of demographic and salary risks on pension expenditure

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Public pension plan in Malaysia is studied to analyze pension expenditure due to salary and demographic risks. Through the literature review and interview session with several officers in public sector, factors affecting pension expenditure are determined. The System Dynamic model is later developed using iThink software to show how demographic and salary changes affect the pension expenditure. Then, by using actual data, the impact of demographic and salary risks on pension expenditure is analyzed. The dynamics simulation model developed in this paper offers a useful tool for analyzing pension expenditure as a result of demographic and salary risks.

Key words: Demographics and salary risk, pension expenditure, system dynamics, public policy.

INTRODUCTION

Pension is a fixed income received by a worker after retirement. Pension is usually a stream payment made in form of annuity to a retired employee. There is also retirement plan where the benefits in form of accumulations can be withdrawn in lump-sum upon retirement. Generally, there are two types of pension plans; Defined Benefit (DB) plan and Defined Contribution (DC) plan. Defined Benefit plan is a pension plan where the retirement benefit is calculated based on last salary, years of employment, retirement age and other factors. Usually in this pension plan, the benefit is paid in form of annuity. Meanwhile, Defined Contribution plan is a retirement plan where each worker possesses own individual account and the retirement benefit is based on employer's contribution and investment return. Generally, a worker in this plan can withdraw his retirement benefit in form of lump-sum of cash. Due to demographic changes and increasing pension spending, pension systems around the world are in flux conditions (Disney and Johnson, 2001). This condition is caused by uncertainties or inherent risk that affects the pension scheme. The existence of risk will also affect the pension expenditure. Among the risks that the sponsor of pension plan particularly in DB plan is exposed to, are demographic risk and salary risk (Chang, 2000). Demographic risk is defined as the increasing risk due to population aging while salary risk refers to the salary growth affecting the cost of providing pension benefits (Chang, 2000). The increasing exposure to risk introduces the world of pension risk management that all sponsors have to realize and investigate properly. Therefore, is the sponsor of pension plan aware of the increasing risk involved? Most importantly, how will the risk influence the pension plan? The complex phenomenon of demographic and salary changes in a pension plan involve numerous factors which are interconnected in a different directions. Hence, this study attempts to develop a policy design model which analyzes pension expenditure as a result of demographic and salary risks.

System Dynamics (SD) methodology had been invented in the early 1960s and it was widely used in numerous areas such as economics, financials, environmental, healthcare, and biological and etc. Founder of System Dynamics, Jay W. Forrester developed the

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methodology to give an understanding of strategic problems in complex systems. Also, SD is widely used to design more successful policies in companies and public policy settings. Nevertheless, there are very limited literatures that discuss the application of system dynamics technique in pension area. SD started to be implemented in pension area when Shimada et al. (1990) built a system dynamics model of Japanese pension annuity system. The simulation model developed by Shimada et al. (1990) was divided into four sectors which are 1): demographic sector-modeling the population in the whole of Japan pension system by classifying the workers by age group, 2) premium income sector-calculating contribution rate from all workers, 3) pension expenditure sector- calculating pension annuity, and 4) reserve of the welfare annuity sector-calculating/analyzing revenue in the pension system. This model compared contribution rate from all workers in Japan with the reserves in the pension fund to assess future condition of the pension annuity system as a result of population aging. Viehweger and Jagalski (2003) developed a SD model of Germany public old age social security system which analyzed the impact of social security reformed from economics perspective. The application of SD in pension area continued when Chaim (2006, 2007) conducted a study to investigate the effectiveness of system dynamics simulation in addressing the problem of risk management in Brazil's pension funds.

Chaim (2006, 2007) combines the methodology of asset and liabilities modeling and system dynamics in analyzing credit risk, market risk, operational risk and liquidity risk in Brazil's pension funds. The objective of his research is to amplify the capability of using SD principles in asset and liability management (ALM) methodology to be risk oriented. By integrated macroeconomics, demographics and actuarial variables, the holistic and dynamic model that had been modeled by Chaim, become a helpful model to be practice in real world. However, Chaim's model was not specifically modeled for either Defined Benefit or Defined Contribution plan. In Defined Benefit pension plan, demographic evolution is an essential part of a pension system since it contributes to the growth of pension liabilities. Chaim only evaluated the pension liabilities by considering the expected liability from the employees' contribution (or employers' contribution) which is almost similar in Defined Contribution pension plan. Meanwhile, Gharakhani (2009) developed a system dynamics model in order to understand the ''pay as you go'' pension scheme from an economic perspective. Among the SD model developed by Shimada (1990), Viehweger and Jagalski (2003), Chaim (2006 and 2007) and Gharakhani (2009) in pension area, none of it was exploring risk in a specific pension plan. This study attempts to develop a policy design model for a specific pension plan, although, this study will analyze pension expenditure for Defined Benefit Pension Plan as a result of demographic risk and salary risk.

STRUCTURE OF MALAYSIA PUBLIC PENSION PLAN

In this research, Malaysia public pension plan is studied to analyze pension expenditure due to salary and demographic risk. In Malaysia, public pension plan is also exposed to demographic risk and salary risk since the public pension plan is based on unfunded Defined Benefit (DB) plan. In this pension plan, the employees' benefits after retirement are determined by their final basic salary and duration of services which is a maximum of 25 years (300 months). Also, the retirement benefits are paid through government budget. This pension plan is available for permanent public workers who have met certain requirements and being confirmed in the service. After confirmation, the public employees get to choose their desired pension plan between two plans offered. If the worker chooses DB plan, he/she has to be in service not less than 10 years in order to be eligible to receive 2% of pension benefit from his/her last basic salary for every accumulated service. Workers who have worked for at least 25 years and above are eligible to receive 50% pension annuity from their last basic salary. The pension annuity will be paid until the worker passes away and the annuity is continuously paid to the eligible family members. The pension benefit received by eligible family member is known as derivative pension. The compulsory retirement age in this pension plan is 55 years old, but the retirement age has been raised up to 56 years old in October 2001 and then to 58 years old effective on July 2008. However, the increment of retirement age does not indicate that the maximum duration of service will also change. The maximum duration of service can also be amended without increasing the retirement age. Therefore, the percentage of pension annuity is depended on the amendment of maximum duration of service. Hence, effective July 2008, public workers who have been in service for 30 years and above are eligible to receive 60% pension annuity from their last basic salary.

There are three groups of employees in Malaysia's public sector, which are top management group, management and professional group and supporting group (supporting group is divided into supporting I and supporting II group). Each group is classified by salary schemes also known as scheme of service; this indicates the priority in establishment and level of salary. In Malaysia's public sector, there are two types of salary changes involved; the salary increased due to yearly salary increment and salary adjustment. Yearly salary increment is an even salary increment for all workers which ranges between 3 - 9% from their basic salary while salary adjustment is defined as an adjustment in a worker's basic salary announced by the policy makers every 5 years period depending on the government's

Table 1. Personnel according to group of service and salary adjustment rate.

Group of service	Salary adjustment rate		
	2000 and 2002 (%)	2003	2007 (%)
Top management	10	RM 110	7.5
Management and professional	10	RM 65	15
Supporting I	10	RM 15	25
Supporting II	10	RM 15	35

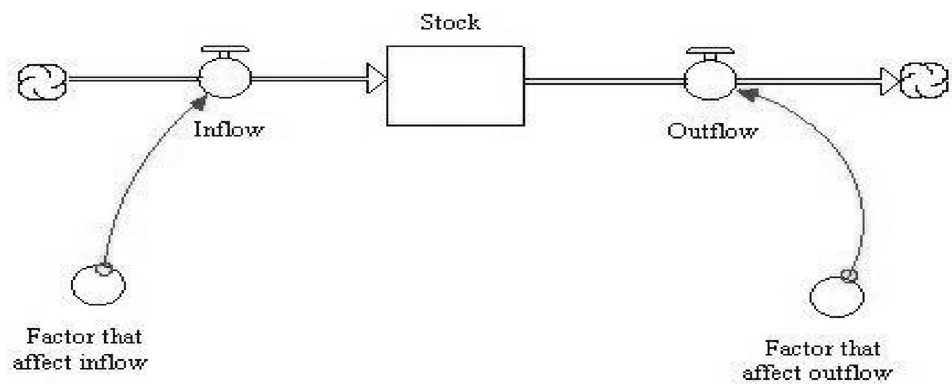

Figure 1. Major elements in System Dynamics model.

financial capability or when there is a need for doing so, like high cost of living etc. Between 1995 and 2008, public workers had received 4 salary adjustments which are in 2000, 2002, 2003 and the latest in 2007. The salary adjustment rate in 2000 and 2002 is a 10% increment from basic salary for all groups of service.

In 2003, salaries have been adjusted not according to the percentage. The salary increment is in amount of RM110 (for top management group), RM65 (for management and professional group) and RM15 (for supporting group). Then, most recently in 2007, the salary adjustment is made by group of service as shown in the Table 1 Workers in top management group received an increment of 7.5% from their basic salary while workers in management and professional group and supporting group received an increment of 15 and 25 to 35% from their basic salary, respectively. Every time the salary adjustment is announced, the pension annuity for all pensioners is adjusted to the same rate as in salary adjustment.

Due to Malaysia's public pension system where the percentage of pension annuity depends on the amendment of maximum duration of service as well as the existence of derivative pension, in this study, demographic risk is defined as the risk in which public workers attain the maximum duration of services at compulsory retirement age and pensioners (or pension recipients) live longer. Also, the salary risk is focusing on the increment of salary when the basic salary is adjusted.

RESEARCH METHODOLODY

System Dynamics (SD) technique exists in early 1960s when Jay W. Forrester of the Massachusetts Institute of Technology invented the methodology to study a non-linear system and feedback control in engineering sciences. With the aid of computer simulation, it is a powerful tool that can be used in understanding complex system. System Dynamics originally based on feedback control theory includes both hard (quantitative) and soft (qualitative) approaches in analyzing the dynamic behaviors of the development and changes of a system (Maani and Cavana, 2000). The strength of SD is that it can help to improve decision making process and policy formation, through its characteristics of incorporating all the relevant cause and effect relationships and feedback loops in a dynamic behavior model of systems. By developing mathematical model using differential equation concept, and by virtue of computer simulation technology, SD is capable of solving a dynamic, varied, interdependent and complex system such as the problem of investigating the impact of demographic and salary risk on pension expenditure.

System dynamic simulation model consists of several types of variables such as stocks, flows, converters, connectors and by using these variables, a system dynamic model can be constructed. Figure 1 depicts major elements in system dynamics model. Stock, which is also known as levels, acts as a reservoir to accumulate quantities (represented by rectangle) and describes the condition of the system. The flows increasing (inflow) and decreasing (outflow) a stock are also known as rates (represented by valve). The condition of stock will depend on the rates while the rates can be affected by a factor affecting inflow or outflow which is known as converter or auxiliaries (represented by circle). Finally, the connectors represent cause and effect links within the model structure represented by the single-line arrow (Maani and Cavana, 2000).

In this research, an interview session was arranged with the Departmental Head of Actuary in Ministry of Finance to investigate

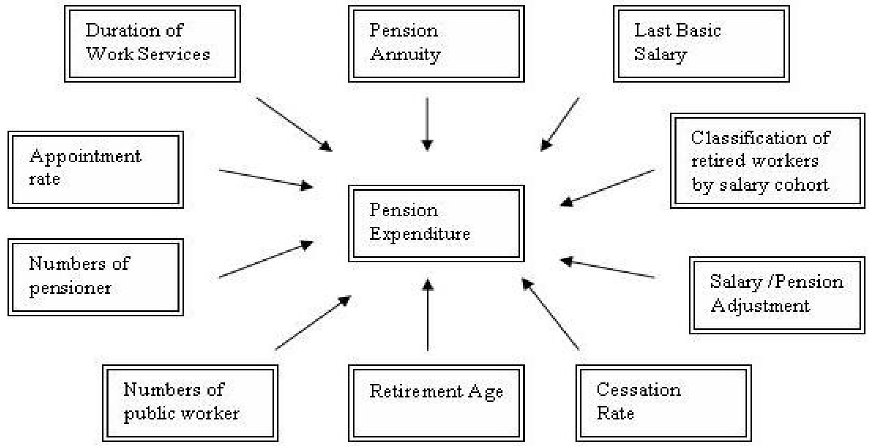

Figure 2. Summary of numerous factors that affect pension expenditure.

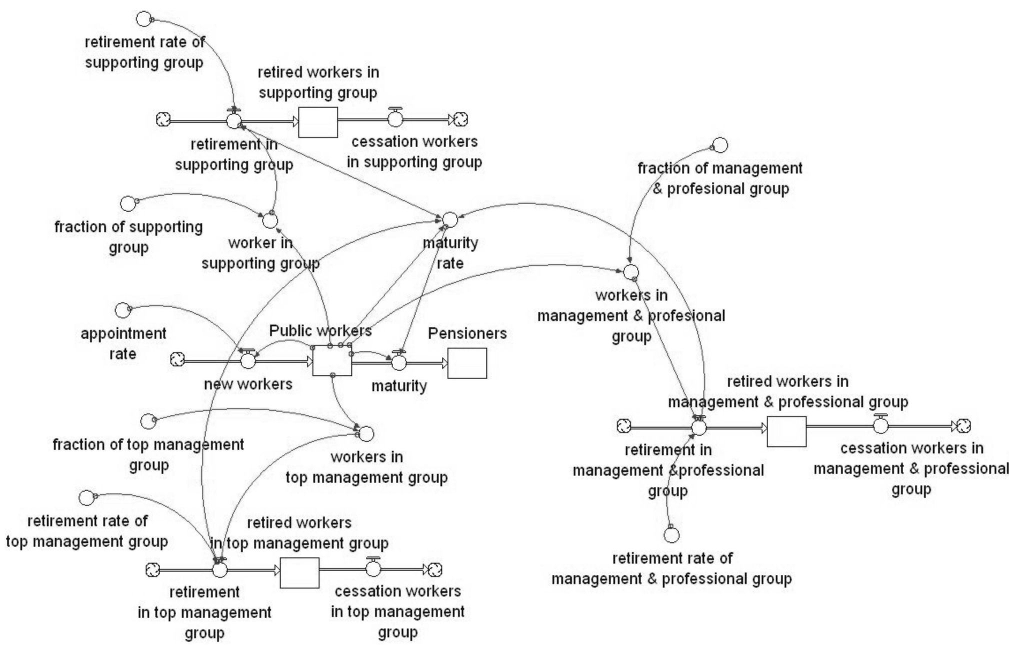

Figure 3. System dynamics model for population sector.

the factors that affect pension expenditure and how they are interrelated. The next interview session was carried out with the Director of Pensions Division in Public Service Department (PSD) in order to gain in depth information regarding the pension system for public workers. After that, few visits were conducted with the senior officers in Pension Division and Deputy Accountant of PSD to further discuss the pension system, available data and related information. Through the literature review of Shimada et al. (1990), Chang (1999), Chang and Cheng (2002), Chaim (2006; 2007) and Jimeno et al. (2008) and from the interview sessions, Figure 2 presents the summary of numerous factors influencing pension expenditure. What can be summarized is that the transition of pension plan's population and salary changes is a complex phenomenon involving numerous factors that are interdependent and interact in different directions. Based on the set of system factors in Figure 2 and information from the interview session, stocks and flows diagram is used to analyze the inter-relationships among these factors.

THE SYSTEM DYNAMICS MODEL

In this research, all factors presented in Figure 2 were transformed into stock and flow diagrams (Figures 3-5) by using iThink software to build the system dynamics model of pension expenditure. The system dynamics model of pension expenditure contains 3 main sectors which are the population, salary scheme and pension expenditure sectors.

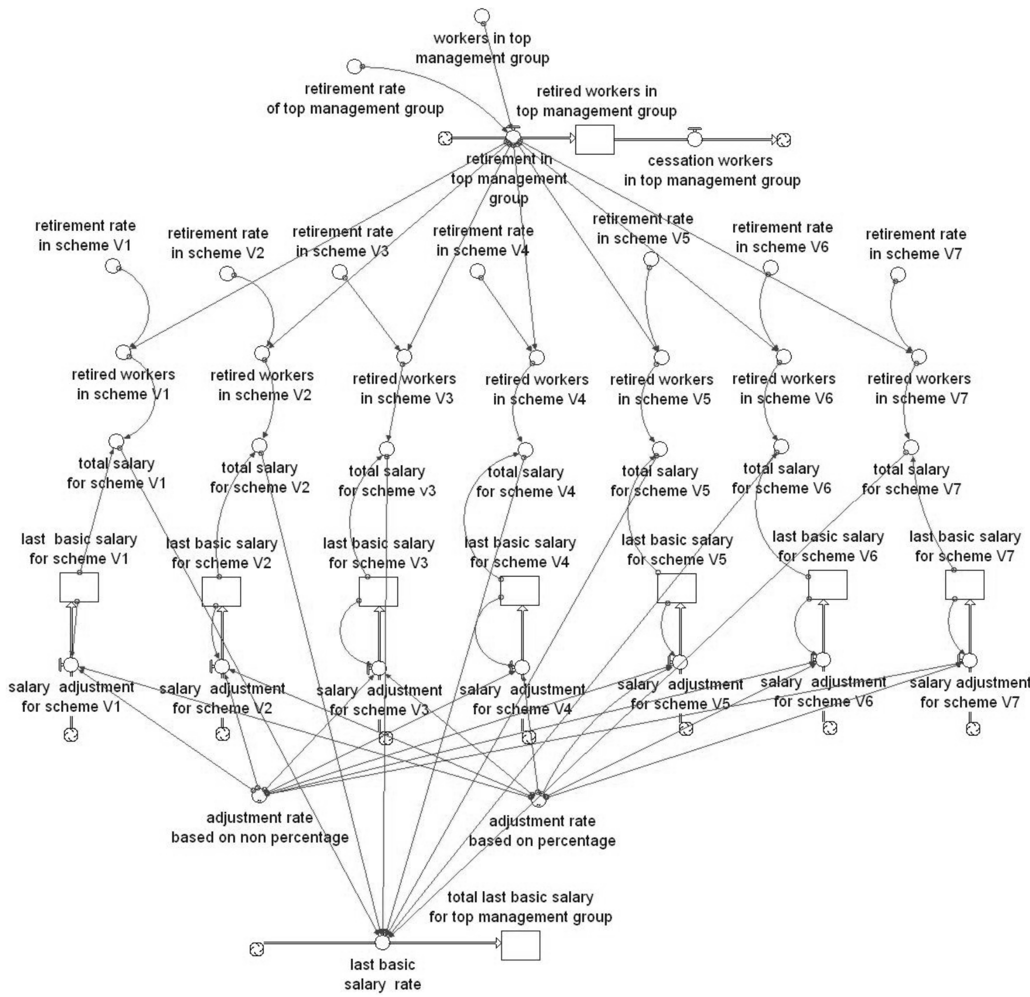

Figure 4. System dynamics model for salary scheme sector.

The population sector

The population sector (Figure 3) illustrates the dynamics that are involved in various population categories. The number of public workers depends on an appointment rate and the numbers of new workers. The public workers consist of top management, management and professional and supporting groups. Therefore, there are three main stocks representing retired workers for each group of service. The total number of retired workers is from each of this group will then affect maturity rate. Maturity rate represents the ratio of workers that reach compulsory retirement age and become pensioners. Also, due the existence of derivative pension, the cessation workers in each group of service represent number of pensioners that no longer received pension annuity. The equations of this sector are (**S** = Stock, **R** = Rate, **C** = Converter):

S $P(t) = P(t-dt) + M * dt$ (1)

R $M = MR * PW$ (2)

C $MR = \sum R_{T,P,S} \big/ PW$ (3)

S $PW(t) = PW(t-dt) + (NW - M) * dt$ (4)

R $NW = PW * AR$ (5)

S $RW_{T,P,S}(t) = RW_{T,P,S}(t-dt) + (R_{T,P,S} - CW_{T,P,S}) * dt$ (6)

R $R_{T,P,S} = RR_{T,P,S} * W_{T,P,S}$ (7)

C $W_{T,P,S} = PW * F_{T,P,S}$ (8)

where P = pensioners, M = maturity, MR = maturity rate, PW = public workers, NW = new workers, AR = appointment rate, $RW_{T,P,S}$ = retired workers in top management, management and professional and supporting groups, $R_{T,P,S}$ = retirement in top management, management and professional and supporting groups, $W_{T,P,S}$ = workers in top management, management and professional and supporting group, $F_{T,P,S}$ = fraction of workers in top management, management and professional and supporting group.

The salary scheme sector

Salary scheme sector (Figure 4) shows the retirement in top

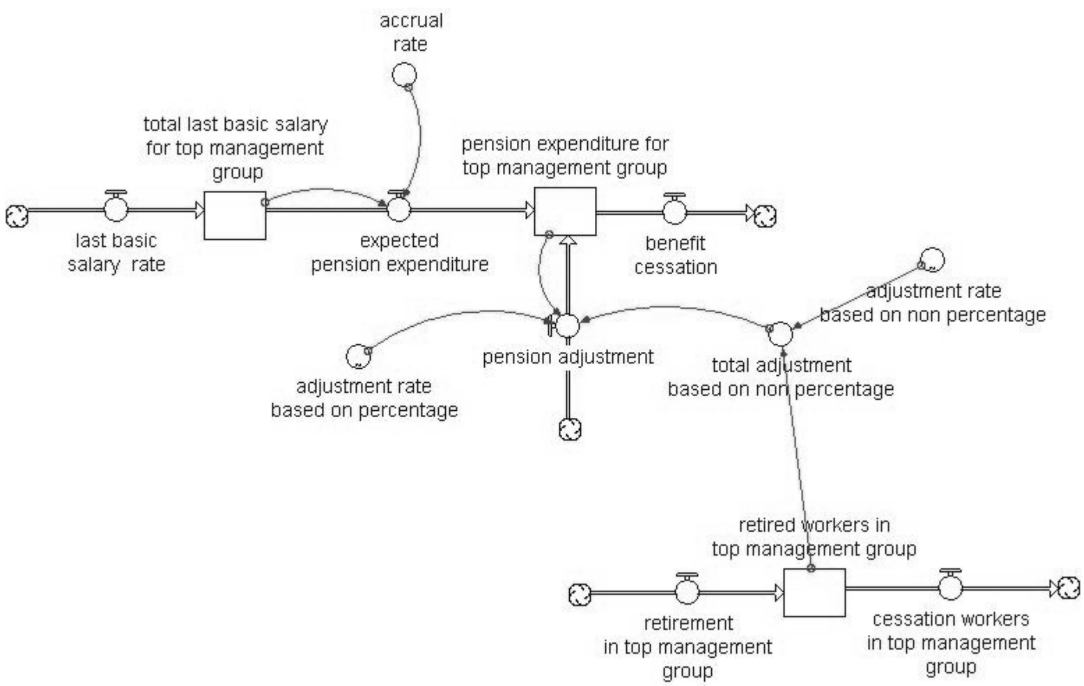

Figure 5. System dynamics model for pension expenditure sector.

management group (similar procedures apply to management and professional and supporting groups) which is categorized by salary cohort also known as scheme of services. Retirement in top management group depends on workers in top management group and their retirement rate. In top management group, there are 7 salary schemes ranging from V1 to V7. The number of retired workers in each salary scheme depends on retirement in top management group and retirement rate. Then, total salary in each salary scheme is influenced by the number of retired workers and the last basic salary in each salary scheme. The last basic salary in each salary scheme is affected by two types of adjustment rates which are based on percentage and non-percentage. Lastly, total salary for all salary schemes determines the last basic salary rate and total last basic salary for top management group. The equations of this sector are (**S** = Stock, **R** = Rate, **C** = Converter):

R $R_T = W_T * RR_T$ (9)

C $RW_{V1-V7} = R_T * RR_{V1-V7}$ (10)

C $TS_{V1-V7} = LBS_{V1-V7} * RW_{V1-V7}$ (11)

S $LBS_{V1-V7}(t) = LBS_{V1-V7}(t-dt) + (SA_{V1-V7}) * dt$ (12)

C $SA_{V1-V7} = (LBS_{V1-V7} * ADRP) + ADRNP$ (13)

S $TLBS_T(t) = TLBS_T(t-dt) + LBSR$ (14)

R $LBSR = \sum TS_{V1-V7}$ (15)

where R_T = retirement in top management group, W_T = workers in top management group, RR_T = retirement rate of top management group, TS_{V1-V7} = total salary in scheme V1-V7, LBS_{V1-V7} = last basic salary in scheme V1-V7, RW_{V1-V7} = retired workers in scheme V1-V7, SA_{V1-V7} = salary adjustment in scheme V1-V7, $ADRP$ = adjustment rate based on percentage, $ADRNP$ = adjustment rate based on non percentage, $TLBS_T$ = total last basic salary in top management group, $LBSR$ = last basic salary rate.

Pension expenditure sector

The pension expenditure sector (Figure 5) is the focus of this study because it is the main interest of the proposed model and is related to all other sectors. In pension expenditure sector, the pension expenditure is calculated for top management group (similar procedures apply to management and professional and supporting groups) by referring to the principles used in Shimada et al. (1990) and Jimeno et al. (2008). From the total last basic salary in top management group, the expected pension expenditure is determined by the total last basic salary and accrual rate. The calculation of pension expenditure includes pension adjustment too. It means when the salary adjustment is announced, the pension annuity for all pensioners is adjusted to the same rate as in salary adjustment. The pension adjustment consists of two types of adjustment rates which are based on percentage and non-percentage. Pension adjustment based on percentage adjustment rate is influenced by the pension expenditure and the percentage of adjustment rate while pension adjustment based on non-percentage adjustment rate is determined by the total numbers of pensioners and the non-percentage adjustment rate, RM 110. Simultaneously, pension expenditure is affected by benefit cessation rate. The equations of this sector are (**S** = Stock, **R** = Rate, **C** = Converter):

S $PE_T(t) = PE_T(t-dt) + (EPE + PA - BC) * dt$ (16)

R $EPE = TLBS_T * ACR$ (17)

R $PA = (PE * ADRP) + TANP$ (18)

C $TANP = RW_T * ADRNP$ (19)

Table 2. Information of the model base run.

Parameter	Value
Appointment rate	0.03
Retirement rate in top management group	0.01
Retirement rate in management and professional group	0.004
Retirement rate in supporting group	0.01
Fraction of top management group	0.01
Fraction of management and professional group	0.22
Fraction of supporting group	0.77
Range of retirement rate for each salary scheme in top management group	0.002 - 0.6
Range of retirement rate for each salary scheme in management and professional group	0.0001-0.5
Range of retirement rate for each salary scheme in supporting group	0.0001-0.2

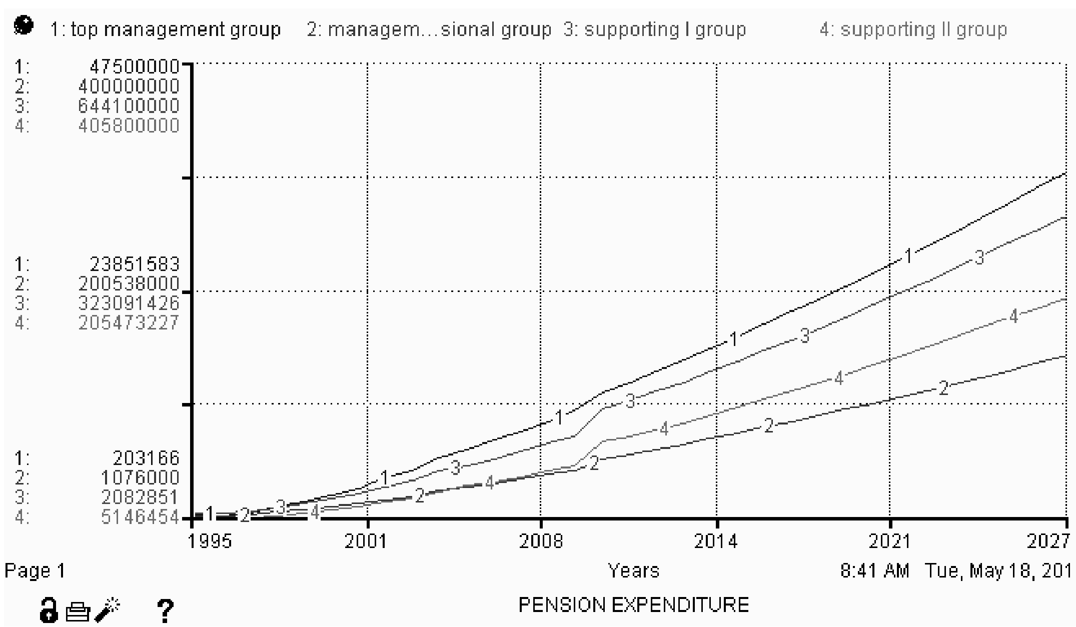

Figure 6. Simulation result of pension expenditure for all group of service.

where PE_T = pension expenditure for top management group, EPE = expected pension expenditure, PA = pension adjustment, BC = benefit cessation, $TLBS_T$ = total last basic salary for top management group, ACR = accrual rate, $TANP$ = total adjustment based on non percentage $ADRP$ = adjustment rate based on percentage, $ADRNP$ = adjustment rate based on non percentage. Pension expenditure for management and professional group and supporting I and II groups is calculated as similar procedures apply to top management group. In management and professional group, the salary schemes range from 41 to 54 schemes while in supporting group, the salary schemes range from 1 to 16 for supporting II group; from 17 to 40 schemes for supporting I group.

SIMULATION AND RESULTS

A sample of actual data provided by Public Service Department is used to simulate the system dynamics model of pension expenditure from 1995 to 2027. The time step for simulation is 1 year and information of the model base-run is listed in Table 2. In the base-run simulation, we assume the initial value of accrual rate is 0.5. This rate implies that all workers have been in service for 25 years and eligible to receive 50% pension annuity from their last basic salary. We also assume starting from 2008 the pension annuity will be paid continuously to the eligible family member if the pensionable officer dies. The base-run simulation results of pension expenditure for top management group, management and professional and supporting I and supporting II groups were presented in Figure 6. With time, it is shown that pension expenditure for all group of service increased. The effect of salary adjustment can be seen obviously after 2008 which pension expenditure is continuously increased for each group of service. Then, we try to simulate the effect on pension

Table 3. Simulation result of pension expenditure in 2027.

Pension Expenditure in 2027 (in Ringgit Malaysia)			
Top management	**Management and professional**	**Supporting I**	**Supporting II**
36,446,689.23	143,339,998.42	432,444,383.8	200,573,870.30

expenditure when accrual rate is rapidly increased to 0.6. The increment of accrual rate to 0.6 means policymaker has to pay 60% pension annuity from workers' last basic salary. Also, the pension annuity will continuously pay until the pensionersb(or pension recipients) die. The results of the simulation in 2027 are particularly shown in Table 3.

From the simulation results, when the accrual rate is increased to 0.6, pension expenditure in 2027 for top management, management and professional, supporting I and supporting II groups reaches approximately RM36,446,689.23, RM143,339,998.42, RM432,444,383.82 and RM200,573,870..30 respectively. It is shown that pension expenditure in each group of service in 2027 increases by 100% from pension expenditure in 1995. Higher pension expenditure was not only affected by the increment of accrual rate, but also affected by higher life expectancies of pensioners (or pension recipients), which implies policy maker has to pay pension annuity for a longer time. Based on the simulation conducted, it can be concluded that demographic and salary changes will continuously affect pension expenditure.

Conclusion

This article describes system dynamics approach in analyzing pension expenditure (particularly in Defined Benefit pension plan) with regards to demographic and salary risks. The system dynamics model in this paper provides a useful way to explain the interactions of numerous demographic and risk factors that exhibit the impact on pension expenditure. Thus, the pension plan's sponsor may fully use the model to evaluate the impact of changes and policy decisions on risk particularly involving demographic and salary risks.

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REFERENCES

Chang KW (2000). A risk management perspective on public pension reform, PhD diss., Boston University.

Chang SC (1999). Optimal pension funding through dynamic simulation: the case of Taiwan public employees retirement system," Insurance. Math. Econ., 24: 187-199.

Chang SC, Cheng YH (2002). Pension valuation under uncertainties: implementation of a stochastic and dynamic monitoring system. J. Risk Insurance., 69: 171- 192.

Chaim RM (2006). Combining ALM and system dynamics in pension funds. In online Proc. of the 24th International Refereed Conference of System Dynamics Society, Netherlands. Available from: http://www.systemdynamics.org/conferences/2006/proceed/index/htm

Chaim RM (2007). Dynamic stochasticity in the control of liquidity in asset and liability management (ALM) for pension funds. In online Proc. of the 25th International Refereed Conference of System Dynamics Society, Boston. Available from http://www.systemdynamics.org/conferences/2007/proceed/index/htm

Disney R, Johnson P (2001). Pension systems and retirement incomes across OECD countries, Edward Elgar, 1-3.

Gharakhani (2009). Towards a better understanding of pension systems. In online Proc. of The 27th International Refereed Conference of System Dynamics Society, Albuquerque, NM, USA. available from: http://www.systemdynamics.org/conferences/2009/proceed/index/htm

Jimeno JF, Rojas JA, Puente S (2008). Modelling the impact of aging on social security expenditures. Econ. Model., 25: 201-224.

Maani KE, Cavana RY (2000). Systems thinking and modeling, understanding change and complexity, Pearson Education N.Z press. 16-70.

Shimada T, Kameyama S, Uchino A, Machida K, Watanabe M (1990). Simulation model of Japanese welfare annuity system. In online Proc. of the 8th International Refereed Conference of System Dynamics Society, Chestnut Hill, USA. http://www.systemdynamics.org/conferences/1990/proceed/index/htm

Viehweger B, Jagalski T (2003). The reformed pension system in Germany, a system dynamics model for the next 50 years. In online Proc. of the 21st International Refereed Conference of System Dynamics Society, New York, USA. July 20-24. available from: http://www.systemdynamics.org/conferences/2003/proceed/index/ht.