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DYNAMIC PROJECT INTERDEPENDENCIES (PI) IN OPTIMIZING PROJECT PORTFOLIO MANAGEMENT (PPM)

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ABSTRACT

Many researchers assess the tools and techniques to optimize the project portfolio management. Most of those tools treat each project within a portfolio as an independent entity. Starting in 2010 onwards, many researchers considered the importance of Project Interdependencies (PI) in defining the Project Portfolio (PP); however, those researchers treated PI as a static condition. Organization strategy has dynamic characteristics caused by internal dynamics as well as external forces. Since the PP is a bridge between organization strategy and the program/project, the PP has to have a dynamic ability, in order to support the organizational strategy dynamics. This research applies an interactive approach using System Dynamics (SD) modelling to represent the PI dynamics as well as a project selection tool/technique within a project portfolio. A case study was conducted with the Bandung Urban Waterworks (PDAM Tirtawening). The outcomes of this research suggest that the model developed by the SD approach is: 1) one of the tools and techniques is to specify the PI dynamics; 2) to determine project priority in order to optimize the project portfolio. SD approach has the ability to challenge an organization’s perception of their project portfolio interdependencies and to enhance strategic decision making capabilities. PI on this research is driven by project outcomes. PI that driven by other reasons, such as by market, resources, knowledge, etc., should be leveraged more, to figure out a complete picture of the PI importance within Project Portfolio Management (PPM).

Keywords: PDAM Tirtawening Bandung; Project interdepencies; Project Portfolio Management; System dynamics

1. INTRODUCTION

Many researchers assess tools and techniques to optimize the project portfolio. They are: (1) capability and capacity analysis; (2) weighting ranking and score techniques; (3) quantitative and qualitative analysis; (4) graphical analytical methods. Figure 1 is an example of portfolio balancing using indicators and criteria, as well as using targeted categories and targeted business units. Each bubble represents a portfolio component (project/program), and the size of the bubble represents an additional variable, such as cost or net present value (NPV). Color may mean another criteria or categorization (PMI, 2013). This figure explains an approach that treats a project within a project portfolio, as an independent entity. From the literature study of previous researches, the importance of project interdependencies has not yet been recognized as

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a tool and technique to optimize the project portfolio and its well-deserved further investigation (Reyck et al., 2005; Rungi & Hilmola, 2011; Teller & Kock, 2013). This research assesses the importance of project interdependencies dynamics in Project Portfolio Management (PPM). The PI model is developed using a System Dynamics approach; and it uses the Bandung Municipal Urban Waterworks (PDAM Tirtawening) data and its current condition as its case study.

1.1. Project Portfolio Management (PPM)

A portfolio is a component collection of programs, projects, or operations managed as a group to achieve strategic objectives. PMI mention that the portfolio components (project or program) may not necessarily be interdependent or have related objectives The portfolio components are quantifiable, that is, they can be measured, ranked, and prioritized (PMI, 2013).

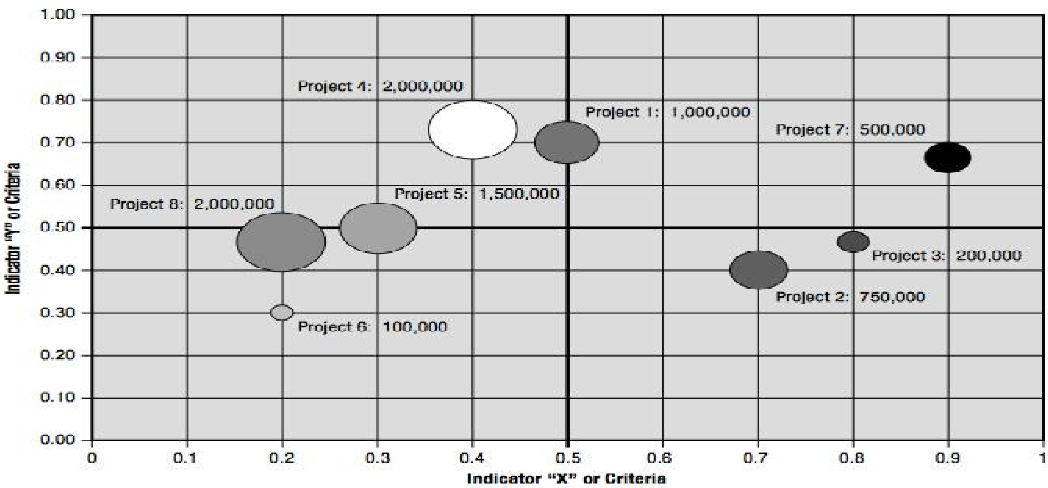


Figure 1 Examples of portfolio balancing

PMI States that portfolio success is measured "in terms of the aggregate investment performance and benefit realisation of the portfolio" (PMI, 2013). Other authors say portfolio success is driven by average project success (Teller, 2013), strategic fit (Teller, 2013), portfolio balance (Teller, 2013; Archer & Ghasemzadeh, 1999; Cooper, 2001). Some researchers suggested that enhancing synergies of knowledge and competence development, sharing of technological platforms, managing customers, or resolving marketing issues, is an important dimension of portfolio success (Tasevska & Toropova, 2013).

Project Interdependencies (PI) are directly related to the exploitation of synergies. PI within PPM practice has a higher project success rate over other portfolios, and a failure to consider interdependencies may lead to market cannibalization. In turn, it may negatively affect 'commercial success' of a project portfolio (Rungi & Hilmola, 2011). Therefore, all these arguments provide a rationale to consider management of PIs to be related to the project portfolio success dimensions.

1.2. Program and Project Management

The Program is a group of related projects, sub-programs, and program activities that are managed in a coordinated way to obtain benefits. The Project is a temporary endeavour undertaken to create unique products, services, or results (PMBOK, 2013). Program is a means of executing corporate strategies and achieving business or organizational goals and objectives (PMBOK, 2013).

1.3. Project Interdependencies

Project interdependencies are among the many factors that must be considered in PPM decisions (Soderlund, 2004). The literature suggests that there is a need for better strategies to manage project interdependencies to develop successful cross-communication capabilities (Platje et al., 1994) PI are driven by multi-typologies (Tasevska & Toropova, 2013). These typologies are: resources, market, knowledge, outcomes and benefits. Resource interdependencies arise from the need for resource sharing between projects (Killen & Kjaer, 2012). Knowledge interdependencies arise when knowledge and expertise generated by one project is used by other projects in a portfolio (Teller, 2013; Rungi & Hilmola, 2011; Platje et al., 1994). Market dependencies occur in the case when a new product enters a market of an already existing product or when the existing market knowledge is used for new products (Zuluaga et al., 2007). Furthermore, they occur when multiple projects compete because of the same or similar objectives (Rungi & Hilmola, 2011). Outcome interdependencies mean that a project is dependent on the results of another project (Teller, 2013; Killen, 2012). Benefit interdependencies occur when the benefits for the organisation increase non-linearly, due to the synergy of implementing two or more interdependent projects, or they can decrease, if the projects cannibalize each other (Tasevska & Toropova, 2013; Zuluaga et al., 2007).

1.4. Benefit of Project Interdependencies

Many previous researchers mentioned the benefit of PI. They are: (1) to easily manage project portfolios (Rungi & Hilmola, 2011; Teller, 2013; Archer & Ghasemzadeh, 1999; Thiry, 2004), (2) to contribute to strategic fit and average project success, (3) to increase help and information sharing (Danilovic & Sandkul, 2005; Formentini, 2011), (4) to manage a common resource pool effectively, to save resources and to deal with many overlapping activities. PI Management offers an ability to overcome difficulties in making decisions, to find better solutions, to have easier control and to see the big picture, which seems to be important for maintaining portfolio balance (Rungi & Hilmola, 2011), (5) reduction in backlogs, reworks, delays and overlap and waste of resources are other benefits (Lycett et al., 2004).

1.5. Negative Effects from Failed Project Interdependencies Management

The failure to consider PIs and subsequently distort portfolio success may cause schedule slippage, cannibalization of resources and markets, resource misuse and shortages (Rungi & Hilmola, 2011; Formentini, 2011; Lycett et al., 2004). These effects may distort budgets, expected durations and revenues of projects in a portfolio and therefore negatively affect "average project success" dimensions. This may in turn cause intracompany or inter-project competition (Lycett et al., 2004), reactive behaviour, short-term problem solving (Engwall & Jerbrant, 2003), failure to exploit organizational learning (Lycett et al., 2004), and other synergies (Lechler & Teichert, 2006), as well as lead to unforeseen risk transferences and a drain on money for any company (Lee & Kim, 2001).

1.6. Project Interdependencies Management

Out of all the previous approaches, PI have static characteristics that require consideration. The project interdependencies are defined as a fixed amount, firmed up since the beginning of the project lifecycle. It is required to declare all the subsets of interdependent projects in advance which do not allow dynamic management performance of the project interdependencies (Blecic et al., 2008). Organization strategies have dynamic characteristics, driven by internal and external changes. PPM's role is to act as a bridge between organizational strategy and the project/program. In order to increase organizational maneuvering capabilities, the organization needs dynamics PPM. It drives the importance of dynamics Project Interdependencies (PI).

1.7. Systems Dynamics (SD)

Forrester pioneered Systems Dynamics during the 1960s as an analytical modelling technique (Srijariya et al., 2008; Sterman, 2000). Sterman said that "The fundamental principle in systems dynamics states that the structure of the system gives rise to its behavior". Individual components in a system do not contain the most complex behaviors, but rather the interactions of the components contain the most complex behaviors. The key goal of systems dynamics thinking is to challenge initial perspectives and consider the long-term effects of actions chosen that could possibly impact the environment, society or moral beliefs (Sterman, 2000).

1.8. Tirtawening–Bandung Municipal Public Waterworks (PDAM) Profile

Balancing the water supply and demand is a challenge for PDAM Tirtawening, Bandung. Water supply management consists of intake, water process installation, reservoir, water piping system management; while water demand management consists of the customer and his/her behavior, tariffs, customer services, customer debt collection, billing and payment management. There is Non-Revenue Water (NRW) that shall be managed by PDAM. PDAM Key Performance Indicators (KPI) are standardized by BPPSPAM (National Supporting Agency for Water Supply System Development), while PDAM's performance progress is audited regularly by the State Development Audit Agency (*Badan Pengawasan Keuangan dan Pembangunan-BPKP*). In order to achieve the KPI target that PDAM Tirtawening set up for their yearly project portfolio, with an upcoming 5- and 10-year annual renewal. PDAM use SWOT (Strength, Weakness, Opportunity, Thread) analysis to defining the project portfolio. SWOT analysis is one of the project portfolio selection approaches that treat a project as an independent entity. SWOT does not consider PI. This approach is running and operating until now. However, the PDAM KPI have never been achieved.

2. METHODOLOGY

Systems Dynamics is an approach to understanding the nonlinear behaviour of complex systems over time using stocks and flows, internal feedback loops and time delays. The dynamic simulation results show the behavior of the systems. The main steps of the systems dynamics modelling and analysis process include: (a) from story to structure; (b) from structure to behavior; (c) causal loop diagrams; (d) stock and flow models; (e) simulation and testing; (f) forecasting; and (g) "what if?" scenarios.

a) From Story to Structure

Urban Waterworks (PDAM) Tirtawening Bandung has many Key Performance Indicators (KPI), they are: (1) maximum operational cost is 80% of its revenue; (2) maximum non-revenue water (NRW) in the distribution area is 15% from the total volume of water out from reservoir; (3) maximum NRW in the Water Processing Installation (IPA)-Reservoir, is 5% from the total water volume out from the IPA. The water consumption per capita is 150 litres/capita/day, and PDAM shall serve a minimum 80% of the population number. Another KPI out of this research scope is PDAM's Human Resource productivity. It can be seen from the 2000–2001, historical data in Table 1 that PDAM Tirtawening Bandung, have never achieved the financial, services and operational targets for the KPI.

b) From Structure to Behavior

The dynamic hypothesis is expressed through representations of cause and effect relationships over time and other corresponding statements, and it is the basic foundation for the building blocks of the SD model (Soesilo & Kurniawan, 2014). It is the basis of the decision making process where a general agreement is developed concerning a quantifiable problem and targeted KPI, which requires participants to question the issues of how a system reacts to surrounding dynamic forces, both at the time in question and the long-term future (Winz & Brierley, 2010).

Table 1 PDAM data from year 2000–2010

Performance criteria	UOM	Average	2.000	2.001	2.002	2.003	2.004	2.005	2.006	2.007	2.008	2.009	2.010
Installed capacity	l/det	31.536	**3.200**	3.220	3.220	2.867,00	2.867	2.867	2937	2.937	2.937	2937	2.937
Maximum capacity	m3/year		**100.915.200**	**101.545.920**	**101.545.920**	**90.413.712**	**90.413.712**	**90.413.712**	**92.621.232**	**92.621.232**	**92.621.232**	**92.621.232**	**92.621.232**
Utilized Production capacity	l/det	2.529,82	**2.385**	2.500	2.506	2.563,00	2.563	2.563	2563	2.496	2.563	2563	2.563
Production Capacity	m3/year		**75.213.360**	**78.840.000**	**79.029.216**	**80.826.768**	**80.826.768**	**80.826.768**	**80.826.768**	**78.713.856**	**80.826.768**	**80.826.768**	**80.826.768**
Installed capacity growth	%	-0,79%		0,63%	0,00%	-10,96%	0,00%	0,00%	2,44%	0,00%	0,00%	0,00%	0,00%
Production capcity growth	%	0,74%		4,82%	0,24%	2,27%	0,00%	0,00%	0,00%	-2,61%	2,68%	0,00%	0,00%
Production	m3/thn	79.709.766,55	**77.858.122**	78.818.507	80.932.949	79.522.079	79.927.567	79.260.303	84.746.149	82.955.111	75.166.458	78.443.964	79.176.223
Production Growth	%	0,26%		1,23%	2,68%	-1,74%	0,51%	-0,83%	6,92%	-2,11%	-9,39%	4,36%	0,93%
Distribution	m3/thn	75.588.762,64	**74.270.653**	74.552.592	77.902.342	76.476.667	76.671.013	76.327.799	81.508.262	79.622.801	73.286.002	70.631.910	70.226.348
Distribution to production fraction	%	95%	95,39%	94,59%	96,26%	96,17%	95,93%	96,30%	96,18%	95,98%	97,50%	90,04%	88,70%
NRW reservoar growth	**%**	5,24%	**4,61%**	**5,41%**	**3,74%**	**3,83%**	**4,07%**	**3,70%**	**3,82%**	**4,02%**	**2,50%**	**9,96%**	**11,30%**
Distribution growth	%	-0,48%		0,38%	4,49%	-1,83%	0,25%	-0,45%	6,79%	-2,31%	-7,96%	-3,62%	-0,57%
Sales and operational usage	m3/thn	35.276.759,36	**33.991.243**	34.769.405	35.833.691	34.094.752	38.727.756	34.131.176	34.495.117	40.577.108	33.202.155	33.159.527	35.062.423
NRW (Non Revenue Water) in distribution gate	0,53	40.315.262,60	40.279.410	39.783.187	42.068.651	42.381.915	37.943.257	42.196.623	47.013.145	39.045.693	40.083.847	37.472.383	35.163.925
% NRW to reservoir volume out	%		54%	53%	54%	55%	49%	55%	58%	49%	55%	53%	50%
NRW fraction	%	53,30%	54,23%	53,36%	54,00%	55,42%	49,49%	55,28%	57,68%	49,04%	54,70%	53,05%	50,07%
Sales growth	%	0,83%		**2,29%**	**3,06%**	**-4,85%**	**13,59%**	**-11,87%**	**1,07%**	**17,63%**	**-18,18%**	**-0,13%**	**5,74%**
NRW Growth	%	-0,01%		0,03%	-1,60%	3,82%	-10,70%	11,71%	4,33%	-14,98%	-16,29%	29,24%	-5,62%
Number of subscriber (customer)	SL		**142.420**	145.534	144.044	128.905,29	168.079,42	144.729,34	127.903,91	140.462	140.073	145155	150.236
Subscriber growth	%	0,63%		2,19%	-1,02%	-10,51%	30,39%	-13,89%	-11,63%	9,82%	-0,28%	3,63%	3,50%
Population number	capita	2.270.892	2.136.260,00	2.146.360,00	2.142.194,00	2.228.268,00	2.232.624,00	2.270.970,00	2.296.848,00	2.339.928,00	2.374.198,00	2.417.288,00	2.394.873,00
Population growth	%	1,16%		0,47%	-0,19%	4,02%	0,20%	1,72%	1,14%	1,88%	1,46%	1,81%	-0,93%
The number of people who have been served	capita	1.465.413	**1.321.372**	1.328.526	1.325.000	1.233.389	1.611.358	1.603.263	1.503.287	1.500.125	1.529.025	1.554.224	1.609.972
Service Coverage area (%)	%	58,85%	61,85%	61,90%	61,85%	55,35%	72,17%	70,60%	65,45%	64,11%	64,40%	64,30%	67,23%

c) Causal Loop Diagrams

The first step in the modelling of systems dynamic structures is the development of causal loop diagrams, which are used to simplify the model and act as preliminary plans of the dynamic hypothesis (Soesilo & Kurniawan, 2014). The causal loop diagrams clearly show that there is strong evidence interdependency relationships between the projects identified in the problem articulation. Figure 2 is a causal loop of demand-supply for the municipal waterworks at PDAM Tirtawening.

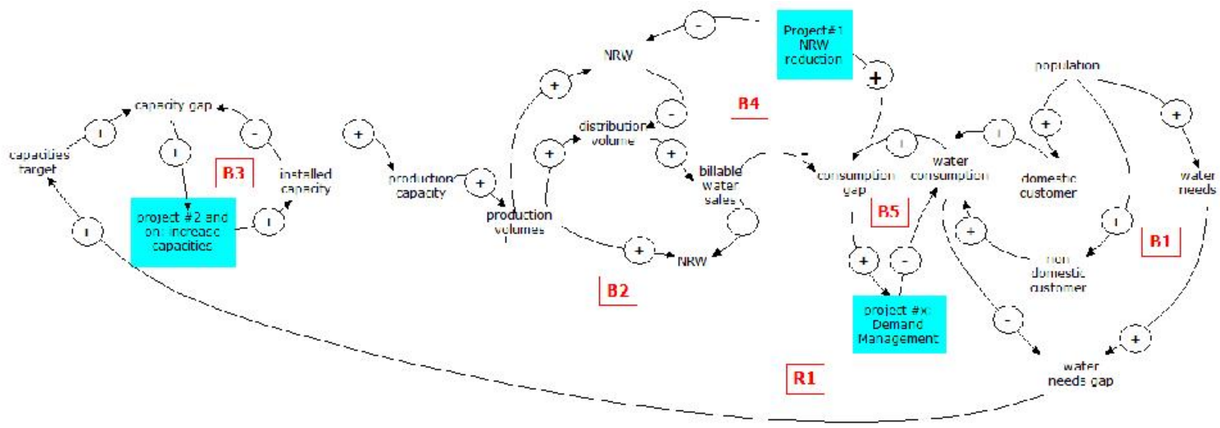


Figure 2 Project Interrelationship in waterworks demand-supply

d) Stock and Flow Models

Building upon the causal loop diagrams, the stock and flow models develop the quantitative aspect of the systems dynamics structure with the aid of computer modelling software. It mathematically maps the flow of information around the system (Srijariya et al., 2008; Winz & Brierley, 2010). The stocks in the dynamic structure represent accumulations within the system, which are only changed through time integrals of the net rates of flow (Winz & Brierley, 2010). Stocks can never have causal links directed into them, but can have causal links directly into flows/fraction or constants (Sterman, 2000). The flows within the system represent the rates of change over time between the stocks (Winz & Brierley, 2010). Constants represent the flow of variables that interact with the causal structure and distinguish the various structures in the problem articulation (Sterman, 2000). Stock and flow diagrams should be exact representations of the causal loop diagrams.

e) Simulation and Testing

Before a further use of the Systems Dynamics model, the validity and reliability tests are required. The test is done which simulates the historical data of PDAM Tirtawening from year 2000–2010. A simulation system resulting from modelling dynamics is compared with the historical PDAM data. If the distinction of the Mean Absolute Error (MAE) between one model and another in terms of historical data is not more than 30%, the model could be stated as a valid model (Soesilo & Kurniawan, 2014). The parameters for the Water System that have been tested in this research are: the intake water volume, the water volume, Water Processing Installation (IPA) output, water volume, reservoir water output, the water volume ready to sale, Bandung Municipal citizens' amount, and the number of PDAM Tirtawening subscribers. All tests for those parameters indicate that the MAE is far below 30%. It means the Systems Dynamics Model is valid.

f) Forecasting

Systems dynamics does not attempt to predict the future, but it is used as a tool to prevent future failures, avoid complications, implement policies and manage change effectively. It should be understood that forecasting is not a scientific activity, but rather a social, political and bureaucratic activity (Sterman, 2000). From running the "as it is" model or what is commonly called, "Business As Usual" (BAU) model, the demand forecast and the supply forecast are as follow.

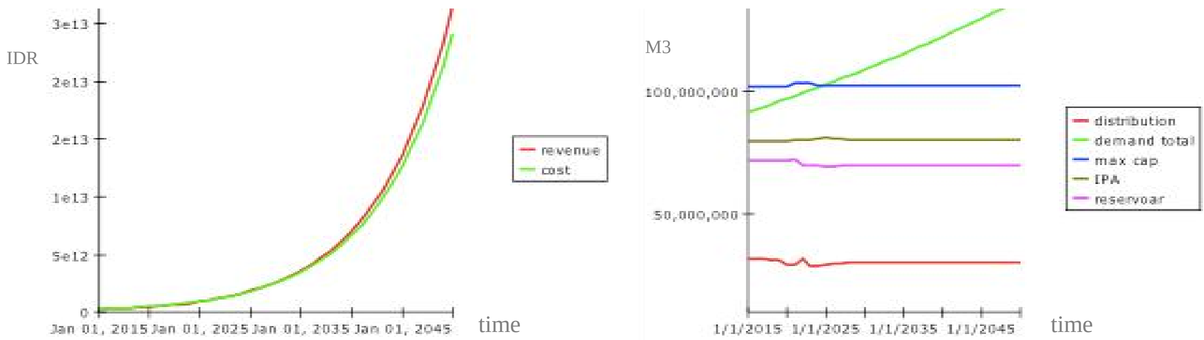


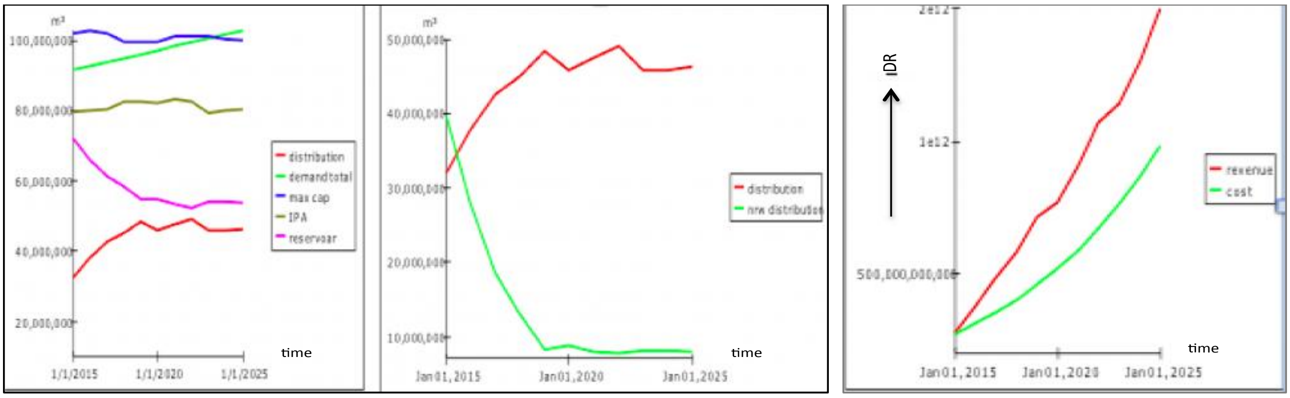
Figure 3 Business as Usual Model (BAU)

From the simulation above (Figure 3), its obvious that PDAM Tirtawening does not have the capacity to set up new and breakthrough initiatives, except for daily maintenance. This is why the gap between demand and supply grows bigger over time. To achieve the KPI, PDAM Tirtawening should set up interventions through project implementations. The prerequisite intervention uses a tariff disparity program in order to get more revenue for the first project funds. The tariff disparity program is not captured in the scope of this research.

Based on the BAU model in Figure 3, the intervention should: (1) reduce NRW project; (2) improve reservoir capacity; (3) increase IPA capacity; and (4) increase maximum capacity; (5) increase the number of subscribers. These 5 projects are PDAM Tirtawening's driver to achieve KPI.

g) ‘What if?’ Scenario

Figure 4a describes the volume output from the distribution system, the reservoir, water processing installation (IPA), intake and the total demand volume of the first intervention for the NRW reduction project, which will be implemented. The distribution volume has a higher output compared with the BAU model. Its output will increase from 29.5Mm^3 in year 2015 to 50Mm^3 in year 2020, with a mean increase of 20.5Mm^3/year. Figure 4b shows the increasing volume in distribution is forecast because the NRW is decreased. However, the growth rate is different. The NRW distribution decreased from 42.3M/m^3 to only 17.3M/m^3; It means the NRW distribution was reduced by 25M/m^3.

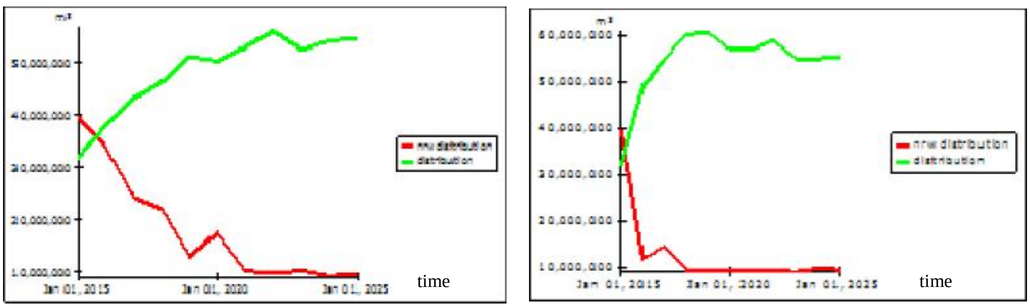


a). Supply-demand volumes b). Distribution vs NRW volumes c) Revenue vs. cost

Figure 4 The first intervention: reducing the non revenue water in distribution

Figure 4c describes the difference between revenue and its cost. The growth rate that is mentioned above was different, because of the reservoir outflow rate limitation. To minimize the gap, a second intervention, a reservoir outflow tune-in project, is needed to increase the reservoir outflow rate.

Directly following the first intervention, a second intervention was implemented to minimize this gap. The simulation results of running the first and second projects consecutively, forecast a distribution volume increase from 50M/m^3 to 57M/m^3. Figure 5 below explains the result of executing the first and second projects together. The simulation should be done repetitively, until the gap between water flow out from reservoir and distribution volume are closer together. Once this condition occurs the profits will be much higher, so the next program/project can be funded.



(a) Result of the first intervention (b) Results of second intervention

Figure 5 Second iteration

The next programs are to increase the capacity of the intake, water processing installation (IPA) and the number of subscribers, in order to achieve the service level KPI. This key performance indicator is the minimum of PDAM service coverage area is 80% of the total Bandung population shall be. Figure 6 below explains the condition when PDAM Tirtawening is able to achieve this KPI.

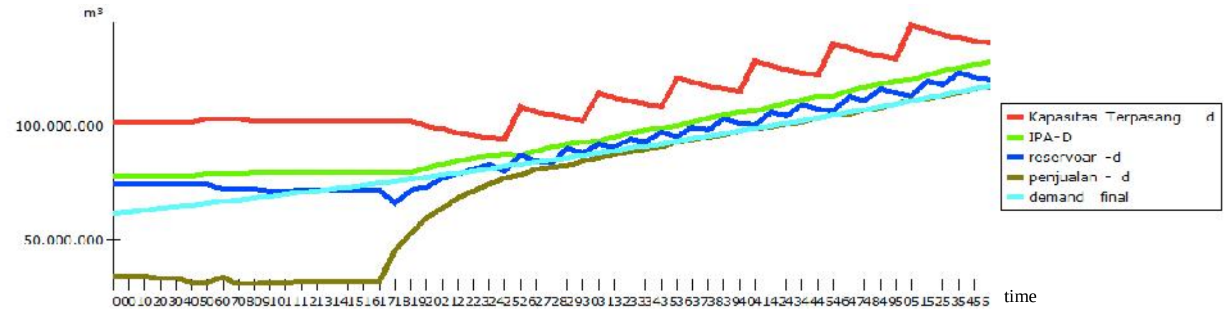


Figure 6 Final intervention: to increase intake, IPA capacities and subscriber number

3. RESULTS AND DISCUSSION

3.1. Project Portfolio Roadmap

Suppose the intervention is started in year 2016. The pre-intervention project is to establish tariff disparity driven by difference water continuity services levels among the Bandung zones. The 2 years profit margin driven by this project, will be able to fund the NRW reduction project and the reservoir outflow tune-in project (second intervention). Suppose the second intervention is started in year 2018 (one year after the tariff disparity project is started), by the end of year 2019, the NRW KPI can be achieved. The next project is to increase the IPA capacity. Suppose this 3rd project is started in year 2020, based on the simulation results into the model, this project duration will be 2 years; So it will be finished in the end of year 2021. From Figure 3, the intake capacity will still able to accommodate the demand volume until year 2026. Referring to the Ministry of Public Work decree: “The Water Supply System Development (SPAM) has to be built to accommodate the upcoming 5 years demand on growth.” Then to meet the capacity forecast for the SPAM (Project No. 4), it will need to be built in year 2021. The increase of the Water Processing Installation IPA (Project No.5) and reservoir capacity project (Project No. 6) is supposed to start in year 2021, too; and thereafter, they are expected to be built once every 5 years to accommodate the Bandung population growth.

Beside focusing on the improvements in service coverage for the KPI, this research also monitors the consumption per capita for domestic as well as non-domestic PDAM subscribers, in order to achieve the standard consumption per capita rate. From the SD model, the minimum consumption per capita KPI, domestic and non-domestic (Project No. 7) can be achieved in year 2020.

Referring to these series of scenarios, 80% of total population can be served by PDAM in year 2041 (Project No. 8). At this time, all the KPI (NRW level, standard consumption per capita, 80% population served) will be achieved. The project portfolio roadmap is shown as follows in Figure 7.

Systems dynamics is proven as a tool to define the dynamic project interdependencies within a project portfolio. While defining the dynamic Project Interdependencies (PI) impacts, Systems Dynamics (SD) approach is able to figure out the project portfolio roadmap. This metodology delivers difference research propositions to be compared with previous researches. This approach able to help PDAM Tirtawening to define a more clear picture of dynamics Project

Portfolio (PP), in order to support their dynamics of organization strategy and to help PDAM Stakeholders in obtaining the same perception of PDAM's problems and their outcomes.

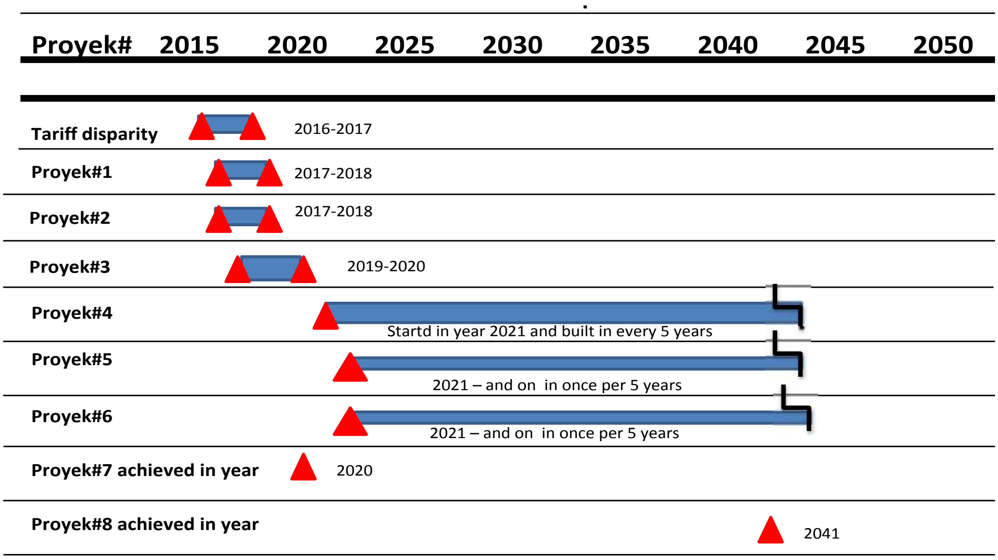


Figure 7 Project portfolio roadmap

4. RECOMMENDATION

The Project Interdependencies in this research are driven by the project outcomes. The research on project interdependencies driven by other reasons, such as by market, resources and knowledge need to be developed. In order to figure out a complete picture of the importance of dynamics Project Interdependencies within Project Portfolio (PP), it is recommended to be developed on a step-by-step basis.

5. CONCLUSION

The research has provided a well-structured foundation for the application of Systems Dynamics (SD) to improve the understanding of Project Interdependencies (PI) within a Project Portfolio (PP). This research shows that the project interdependency within a project portfolio is non-linear and has dynamic characteristics and to show the ability to be a bridge for dynamics corporate strategies and programs or projects, such as for the PDAM Tirtawening, Bandung.

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