Computation of Reliability, Average Reliability, and Maintainability of Service Demand Fulfilment Dynamically using System Dynamics

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***Abstract*— An enterprise not only needs information about the time-based service performance (reliability and maintenance of services) but also need to know the effect of time variables on the dynamic of both service performance and demand. Therefore, this article proposes the computation of reliability and maintainability as the service performance of the enterprise based on service time of demand fulfillment, as well as the use of average reliability that affected to the demand at specific duration time. To solve this problem, system dynamics simulation is carried out on the dynamic model which consists of the interrelationship variables and the delay time. The dynamic model is developed based on the conceptual model represented by a causal loop diagram (CLD). Next, CLD is converted into a stock and flow diagram (SFD), so the dynamic model can be simulated to achieve the proposed of this article. The result of simulation shows the decrease of service time variables can cause either decrease, increase or no change to the total, the event number, and the average of the reliability, average reliability, and maintainability of service and all services, as well as its demand.**

***Keywords*—** *Service performance; Service time of demand fulfillment; Reliability; Average reliability; Maintainability; System dynamics; Enterprise.*

1. Introduction

Time is an important variable that can be used as a basis to compute a service performance and has an effect on the change of other variables. For example, time effects to value consumers place on air travel on-time performance [1]. A time-based performance measure can also be found at the departmental level, such as inventory system [2], failures in e-retailing [3]. At the lower level, time-based performance is called reliability.

Many articles have been presented on reliability topics, such as reliability on the machine [4], reliability on the web service of mobile computing [5], reliability on the IT infrastructure [6], and reliability on the integration of storage systems within distribution networks [7]. Reliability related with another time-based performance so it emerges reliability and maintainability [8], [9]. Based on the work of [10], [11], it could be said the reliability of service is different from the reliability of the machine. A value of machine reliability is in line with the time duration achieved that computed as $R = 1 - f(x)$ [11], while service reliability is opposite to time duration achieved so that computed as $R = f(x)$, where $f(x)$ is an unreliability function. Until currently, reliability has implemented in many service cases, such as on hospitals [12], on improving bus service [13], and on emergency medical service vehicle resources [14].

Based on the description of reliability above and in the related work (Section 2), there are no articles discuss reliability and maintainability deeply in an enterprise case. Therefore, this article proposes the computation of reliability and maintainability as the service performance of the enterprise based on service time of demand fulfillment, as well as the use of average reliability that affected to the demand. Where this computation is done over a specific duration time. The method used to solve this problem is system dynamics simulation (SDS)

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which allows the computation of reliability, average reliability, maintainability, and demand that are dynamical. The SDM is carried out on the dynamic model (DM) consisting of the interrelationship variables and the delay time that form a closed system containing the negative feedbacks that are representative of the enterprise. DM is developed based on the conceptual model represented by a causal loop diagram (CLD). Next, The CLD is converted into a stock and flow diagram (SFD), so the DM can be simulated using the system dynamics tool to achieve the proposed of this article.

The enterprise that studied in this article is a company that produces products, provides services and warranties to customers. In providing products and services to customers, an enterprise may cooperate with one or more enterprises [15], [16], [17]. The example of this enterprise is Hewlett Packard, IBM, Dell that have cooperation with the supplier, distributor, and marketer [18], [19], [20].

In accordance to show the service time variables can have negative, positive, and no effect to reliability, average reliability, maintainability and demand, some scenarios are specified to simulate the SFD. The result of SDM shows the decrease of service time variables (service time of demand fulfillment and its meantime, meantime of reliability function) can cause either decrease, increase or no change to the total, the event number, and the average of the reliability, average reliability, and maintainability of service and all services, as well as its demand.

2. Related Work

The studies about the time effect, reliability, and maintainability have been conducted by many authors. Therefore, this section describes the articles related the computation of reliability and maintainability the have been studied by the authors. Some articles have been presented briefly in Section 1 and will be described in more detail in this section.

The study by [1] showed how much value provided by consumers place on air travel on-time performance (OTP) and computes on-time performance-related marginal investment costs per minute of improvement necessary to achieve specific percent reductions in arrival delay minutes. They computed the effect of on-time performance on increasing investment in the airline so that air travel still gets a profit. Using counterfactual experiments, the authors found a 10% reduction in arrival delay minutes (improved OTP) results in an increase in variable profit by a mean 3.95 percent.

The study by [2] conducted a simulation study to examine the important effect of lifetime variability of perishable items on the performance of inventory system. Perishable items that observed are groceries without any description of the expiration date, such as fresh fruits, vegetables, flowers, and seafood. The authors concluded the lifetime variability have an important effect on the total cost of inventory. On the lifetime variability, if the coefficient of variation decreases from 1 to 0.44, the results indicate that the cost improvement ranges from 11% (for fixed ordering cost per order = 50, purchase cost per unit of product = 15, lost sales cost per unit of product = 20 and outdated cost per unit of product that perishes in stock = 5) to 46% (for fixed ordering cost per order = 100, purchase cost per unit of product =5, lost sales cost per unit of product =40 and outdated cost per unit of product that perishes in stock = 15).

The study by [5] proposed a Reliable Service Architecture using Middleware (RSAM) to achieve the web services reliability in mobile cloud computing. The RSAM focused on ensuring and tracking the request execution under the communication limitations and service temporal unavailability. The authors conducted experiments to compare the reliable service architecture with the traditional one and covered several cases to prove the achievement of reliability. By consider request data size, response size, and consuming time, the experimental result is shown as follows. The variety in the request data size (25, 53, 55 bytes) then the extra request data size is the same (226 extra bytes). The difference in the response size between Middleware components versus direct cloud, the experimental tries of different web services that vary in the response data size are 2 MB, 4.5 MB, and 7 MB. The experimental tries of different web services that vary in the response data size as (3 KB, 191 KB, 2 MB, 4.5 MB, and 7 MB), the consuming time of Middleware component versus the direct cloud is 1 s, 2 s, 28 s, 44 s, and 67 s.

The study by [12] identified the most critical factors of 400 hospitals in developing country related to service quality (SERVQUAL), which reliability is one of SERVQUAL dimensions (i.e., tangibility, reliability, responsiveness, assurance and empathy). Based on 3 proposed hypotheses (H1: All the SERVQUAL dimensions equally impact the patient satisfaction, H2: Age, gender, and marital status impact the evaluations of the patients in a typical developing country, and H3: Patient satisfaction has a mediating role in increasing the patient loyalty), after the path analysis, the result showed that the reliability and responsiveness contribute significantly to patient satisfaction, with standardized estimate 0.55 and 0.160.

The study by [8] studied the effects of manual refactoring commits on source code using a maintainability model. The authors analysed the source code and measured the maintainability of 6 large-scale, proprietary software systems in their manual refactoring phase. The authors also analysed 2.5 million lines of code and studied the effects on maintainability of 315 refactoring commits, which fixed 1273 coding issues. They found that single refactoring only make a very little difference (sometimes even decrease maintainability), but a whole refactoring period can significantly increase maintainability, which can result not only in the local but also in the global improvement of the code.

The study by [9] presented a concept maintainability on actual demand of product. The authors used a theory of product lifecycle to evaluate and computed index system of product maintainability with considering inherent attributes and external factors. In the case study of loader's transmission, the authors improve some indicators, so the maintainability of the initial transmission 0.778 increase to 0.860.

Each article described above discussed (effect of on-time performance on increasing investment in the airline and effect of lifetime variability of perishable items on the performance of inventory system), reliability (reliability of web services in mobile cloud computing and service reliability contribution to patient satisfaction) and maintainability (using maintainability to know effect manual refactoring commits on source code and maintainability on actual demand of product) independently. In this article, reliability and maintainability are used together (rather than considering reliability only such as in [5], [8], [9], [12] to computed time-based performance of enterprise dynamically to know the performance of service time and its ability to achieve the target. Furthermore, this article proposes a positive relationship between the average reliability and demands, which is tested using the goodness of fit test.

3. Enterprise Case Study

The beginning of the problem in this article is the case study of the demands come from customers to the enterprise. The demands from customers consist of the IT product, IT service, and warranty demand from IT product and IT service that received, where these demands have interrelated another. Some IT product demand from the customer may cause the IT service demand with a delay time, and vice versa, some IT service demand from the customer may also cause the IT product demand with a delay time. Next, after a specific of time, both IT product demand and IT service demand cause warranty demands that must be provided by the enterprise.

In this case study, each demand of enterprise is computed the service time of demand fulfillment that can be carried out by the enterprise. Next, this service time is used as the base of computation of service performance of the enterprise.

Therefore, in accordance with the description of demands mentioned above, Section 3.1 describes in detail type of IT product demand, IT service demand, and warranty of both demand for IT product and IT service. Next, Section 3.2 describes the computation of service performance that is computed to each service and parallel arrangement of all service (as representative of the enterprise service performance).

3.1 Type of enterprise demands

To detail the explanation on the previous section, this section describes the type of demand on the enterprise. IT product demand consists of three demand types; independent product demand (IPD), dependent product demand that affected by independent service demand for every 15 days (DPD_{ISD}), and dependent product demand that affected by the average reliability of enterprise (DPD_{RA}) for delay time 30 days. The sum of these three demand types is called total product demand (PDT).

IT service demand also consists of three demand types; independent service demand (ISD), dependent service demand that affected by independent product demand for every 15 days (DSD_{IPD}), and dependent service demand that affected by the average reliability of enterprise (DSD_{RA}) for delay time 30 days). The sum of these three demand types is called total service demand (*SDT*).

After delivering PDT and SDT (10 days), the enterprise has the mandate to fulfill the warranty of both demands that are the warranty of PDT (PWD) and the warranty of SDT (SWD). Therefore, Fig. 1 shows the detail of type and relationship of demands in the enterprise.

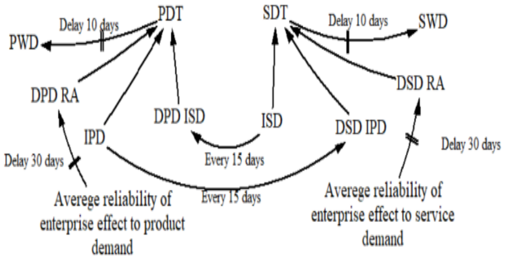


Figure 1. Type and relationship of demands in the enterprise

3.2 Reliability, average reliability, and maintainability

Based on the fulfillment of the demands that described in Section 3.1, the enterprise has two kinds of reliability, the first is the reliability of individual service (R_i) and the second is the reliability of enterprise (R_{Ent}). R_i is computed based on service time of demand fulfillment ($STDF$) of PDT, SDT, PWD, and SWD. PDT has two $STDF$ (product delivery (PD) and product installation (PI)). Each SDT, PWD, and SWD has $STDF$ (service completion (RC), product warranty (PW), and service warranty (SW), respectively). Next, the reliability of $PD, PI, SC, PW,$ and SW is called reliability of individual service and computed as $R_i = f(x)$, with $f(x)$ is an exponential distribution. Therefore,

$$R_i = 2.718^{-\frac{1}{MTRF_i \,.\, STDF_i}} \qquad (1)$$

for $i = PD, PI, RC, PW$ and SW.

with *MTRF* (meantime of the reliability function) is the same as meantime of $STDF$ while $STDF$ is generated from the exponential random number generator when $PDT, SDT, PWD,$ and $SWD > 0$.

R_{Ent} is computed based on the set of service reliabilities ($R_{PD}, R_{PI}, R_{SC}, R_{PW}$ and R_{SW}) that arranged in the parallel arrangement. Therefore,

$$R_{Ent} = 1 - \prod(1 - R_i) \qquad (2)$$

for $i = PD, PI, SC, PW,$ and SW.

The enterprise has two kinds of average reliability (average reliability of individual service (RA_i) and average reliability of enterprise (RA_{Ent})). RA_i is computed based on the number of service reliabilities ($\sum R_i$) divided by the number of reliable services ($\sum RS_i$) for every 10 days. Therefore,

$$RA_i = \frac{\sum R_i}{\sum RS_i} \qquad (3)$$

where $RS_i = \begin{cases} 1 \text{ if } R_i > 0 \\ 0 \text{ if } R_i = 0 \end{cases}$

or $i = PD, PI, SC, PW,$ and SW

RA_{Ent} is computed based on the number of RA_i divided by the number of $RA_i > 0$ for every 10 days. Therefore,

$$RA_{Ent} = \frac{\sum RA_i}{\sum RA_i > 0} \qquad (4)$$

for $i = PD, PI, SC, PW,$ and SW.

The enterprise also has two kinds of maintainability (maintainability of services (M_i) and maintainability of enterprise (M_{Ent})). M_i is computed if $0 < STDF_i \leq UL_{STDF_i}$ (specific condition for M_i), where UL_{STDF_i} is upper limit of UL_{STDF_i}. Therefore, if $0 < STDF_i \leq UL_{STDF_i}$, M_i is computed as follows.

$$M_i = \frac{R_i}{R_t} \qquad (5)$$

for $i = PD, PI, SC, PW,$ and SW

M_{Ent} is computed based on the set of service maintainability ($M_{PD}, M_{PI}, M_{SC}, M_{PW}$, and M_{SW}) that arranged in parallel. Therefore,

$$M_{Ent} = 1 - \prod(1 - M_i) \qquad (6)$$

for $i = PD, PI, SC, PW,$ and SW

In order to clarify the enterprise case study, Fig. 2 shows the relationship among the demands, reliability, average reliability, and maintainability that described in the fault tree diagram. In this diagram, the correspond of R_i, RA_i, and M_i to R_{Ent}, RA_{Ent}, and M_{Ent} uses an OR gate (as a parallel relationship).

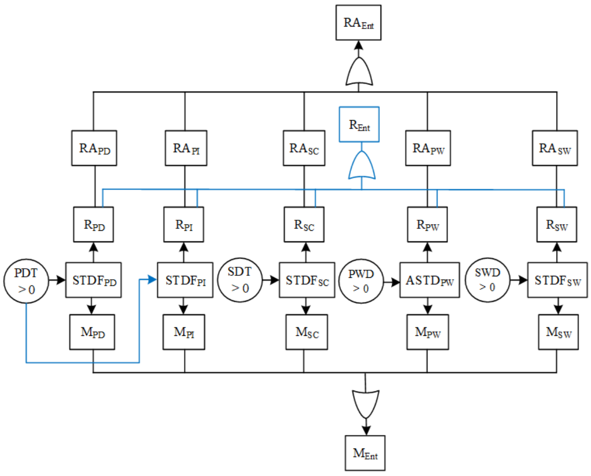


Figure 2. Fault tree diagram of relationship between demands and reliability, average reliability, and maintainability

In order to form a positive relationship between average reliability of enterprise (RA_{Ent}) and demands (DPD_{RA} and DSD_{RA}) then two variable is specified (ERA_{PD} and ERA_{SD}) which is a variable with a lookup function. ERA_{PD} is the lookup function of the effect RA_{Ent} to DPD_{RA} and ERA_{SD} is the lookup function of the effect RA_{Ent} effect to DSD_{RA}. In the lookup function, if the effect of RA_{Ent} to DPD_{RA} and DSD_{RA} are considered as $x_{DPD_{RA}}$ and $x_{DSD_{RA}}$ then ERA_{PD} and ERA_{SD} are considered as $y_{DPD_{RA}}$ and $y_{DSD_{RA}}$. ERA_{PD} and ERA_{SD} are computed as follows.

$$y_{DPD_{RA}}\left(x_{DPD_{RA}}; RA_{Ent_{min}} \leq x_{DPD_{RA}} \leq RA_{Ent_{max}}\right)$$

$$= \begin{cases} 0, \text{if } 0 \leq \ RA_{Ent} \leq x_{DPD_{RA1}} \\ y_{DPD_{RA1}}, \text{if } x_{DPD_{RA1}} < RA_{Ent} \leq x_{DPD_{RA2}} \\ y_{DPD_{RA2}}, \text{if } x_{DPD_{RA2}} < RA_{Ent} \leq x_{DPD_{RA3}} \\ . \\ . \\ y_{DPD_{RAn}}, \text{if } x_{DPD_{RAn}} < RA_{Ent} \leq x_{DPD_{RA(n+1)}} \end{cases} \tag{7}$$

$$y_{DSD_{ARE}}\left(x_{DSD_{RA}}; RA_{Ent_{min}} \leq x_{DSD_{RA}} \leq RA_{Ent_{max}}\right)$$

$$= \begin{cases} 0, \text{if } 0 \leq \ RA_{Ent} \leq x_{DSD_{RA1}} \\ y_{DSD_{RA1}}, \text{if } x_{DSD_{RA1}} < RA_{Ent} \leq x_{DSD_{RA2}} \\ y_{DSD_{RA2}}, \text{if } x_{DSD_{RA2}} < RA_{Ent} \leq x_{DSD_{RA3}} \\ . \\ . \\ y_{DSD_{RAn}}, \text{if } x_{DSD_{RAn}} < RA_{Ent} \leq x_{DSD_{RA(n+1)}} \end{cases} \tag{8}$$

Next, all of the demands, reliabilities, average reliabilities, maintainabilities, and average reliabilities effect to demands that have been described in this section might be called as the DM variables of service performance computation in the enterprise.

4. Modelling

Furthermore, after the explanation of the case study, this section explains the step of modelling and simulation. Modelling step is done by developing a causal loop diagram (CLD) to represent the conceptual model of the problem. The next work is making a stock and flow diagram (SFD) using the specific system dynamics tool so that DM can be simulated. Next, the step is the simulation of SFD to achieve the proposed that stated in Section 1 (Introduction), that is the computation of reliability and maintainability as the service performance of the enterprise based on service time of demand fulfillment, as well as the use of average reliability that affected to the demand.

4.1 Causal loop diagram

As the conceptual model, CLD is shown in Fig 3. The CLD consists of the variables that have been described in Section 3 and the auxiliary variables (i.e., meantime of product delivery, product installation, service completion, product warranty, and service warranty).

The CLD form a closed system which contains negative feedback (negative feedback is caused by the negative relationship between $STDF_i$ and R_i) and delay (//). In this CLD, there are still the disconnected variables (i.e., reliability and maintainability of the enterprise) in which other variables should be added to the disconnected variables to form a closed system. These other variables are accumulative maintainability of enterprise, maintainability out of enterprise, accumulative reliability of enterprise, and reliability out of the enterprise that is added in next step (construction of stock and flow diagram). This CLD concept is as described by [21], [22], [23].

4.2 Stock and flow diagram

As the representative of DM in the case study, SDF is shown in Fig. 4 that consists of the variable of flow, stock, and auxiliary [24], [21], [25]. Based on this SFD, the simulation step can be done to compute the reliability, maintainability, average reliability that affected to the demand.

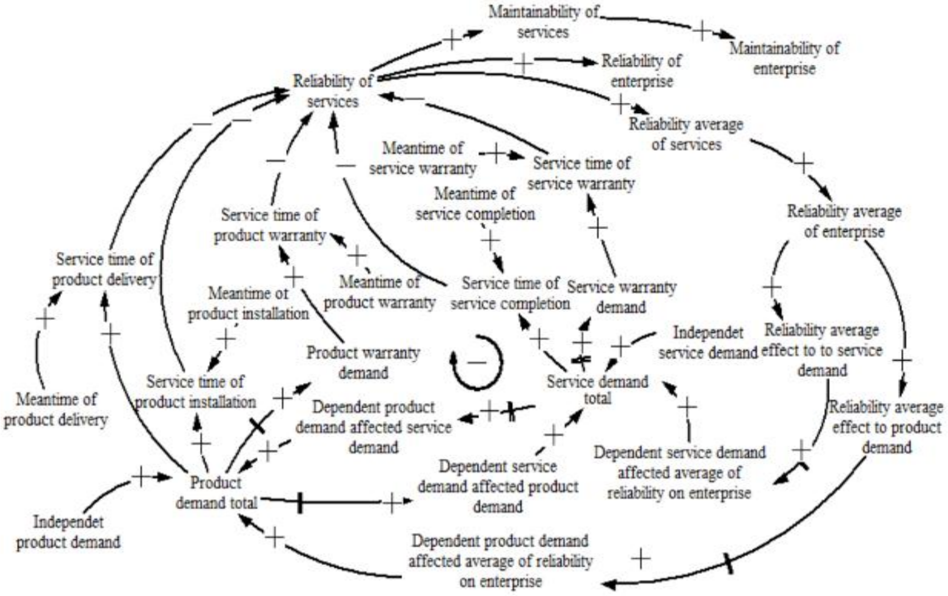


Figure 3. CLD of reliability, average reliability, and maintainability of services and enterprise as well as the effect of average reliability to the demands

4.3 Simulation

In order to simulate the SFD (SD simulation), some value of the variables must be set as shown in Table 1 (set as Scenario A). Initially, the SD simulation is run at $T = 0$ to $T = 10$ to show the logical relationship between the variables (shown in Table 2).

Based on SD simulation output (from $T = 0$ to $T = 10$), the demand shows logical relationship with other variables, such as at $T = 0$ if $SDT = 1$ then $R_{SC} =$ 0.601 (Eq. 1) and at $T = 10$ $SWD = 1$ with $R_{SW} = 0.626$ (Eq. 1). A reliability of service has the logical relationship with others variables, such as at $T = 0$ if $R_{SC} = 0.601$ then $R_{Ent} = 0.601$ (Eq. 2) and at $T = 0$ to $T = 9$ $R_{SC} = 0.601, 0.398, 0.698,$ and 0.565 respectively, then at $T = 10$ AR_{SC}=0.565 (Eq. 3). At $T = 10$ RA_{PD}, RA_{PI}, and $RA_{SC} = 0.677, 0.706$ and $, 0.565$ respectively, then $RA_{Ent} = 649$ (Eq. 4). Next, At $T = 1$ if $R_{PD} = 0.497$ and $R_{PI} = 0.631$ then $M_{PD} = 621$, $M_{PI} = 0.789$ (Eq. 5), and $M_{Ent} = 0.920$ (Eq. 6). The value of R_i, R_{Ent}, RA_i, and RA_{Ent} is minimal 0 and maximal 1 while M_i and M_{Ent} is possible > 0 if $R_i > R_T$.

Table 1. Value of variables

Variable	Value (unit)
Min. & max. of IPD	0 & 3 product/day
Min. & max. of ISD	0 & 2 service/day
Min. & max. of $STDF_{PD}$	1.75 & 3.78 day
Min. & max. of $STDF_{PI}$	0.6 & 0.96 day
Min. & max. of $STDF_{SC}$	2.76 & 6.92 day
Min. & max. of $STDF_{PW}$	0.55 & 0.94 day
Min. & max. of $STDF_{SW}$	1.25 & 1.95 day
Meantime of $STDF_{PD}$	2.21 days
Meantime of $STDF_{PI}$	0.702 days
Meantime of $STDF_{SC}$	4.29 days
Meantime of $STDF_{PW}$	0.651 days
Meantime of $STDF_{SD}$	1.47 day
R_T	0.8
Unit check 1	1/day
Unit check 2	1/dmnl.dmnl.dmnl.dmnl
$UL_{STDF_{PD}}$	0 to 2.21 days
$UL_{STDF_{PI}}$	0 to 0.702 days
$UL_{STDF_{SC}}$	0 to 4.29 days
$UL_{STDF_{PW}}$	0 to 0.651 days
$UL_{STDF_{SW}}$	0 to 1.47 days

Next, SDS is run from $T = 0$ to $T = 100$ so get the complete output, this condition might called as Scenario A. The output in the form the dynamic behaviour during the simulation time so it is presented in the graphics (Fig. 5). In the graphics, both product and service demand have a unit (product/day and service/day) while reliability, average reliability, and maintainability are dimensionless.

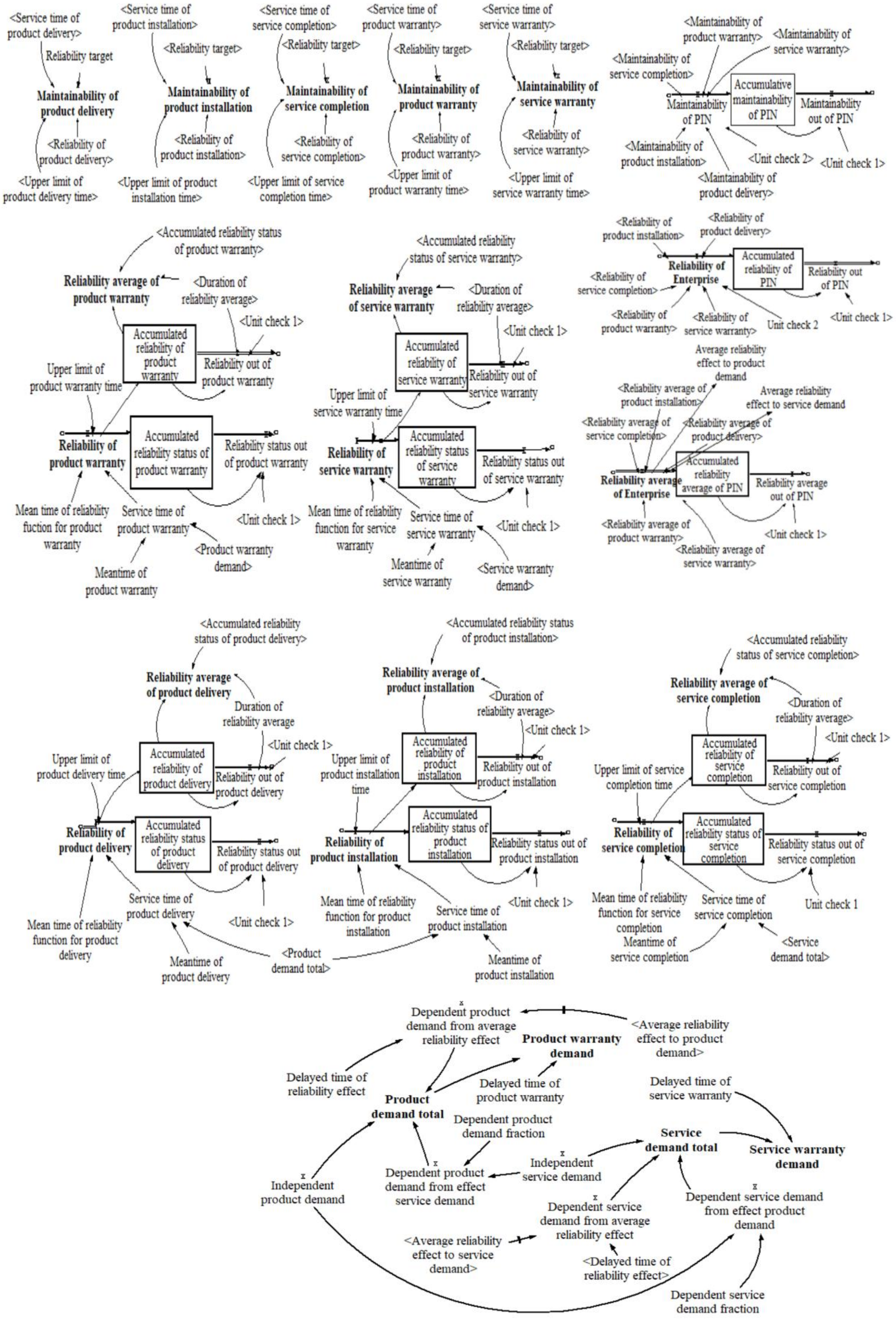
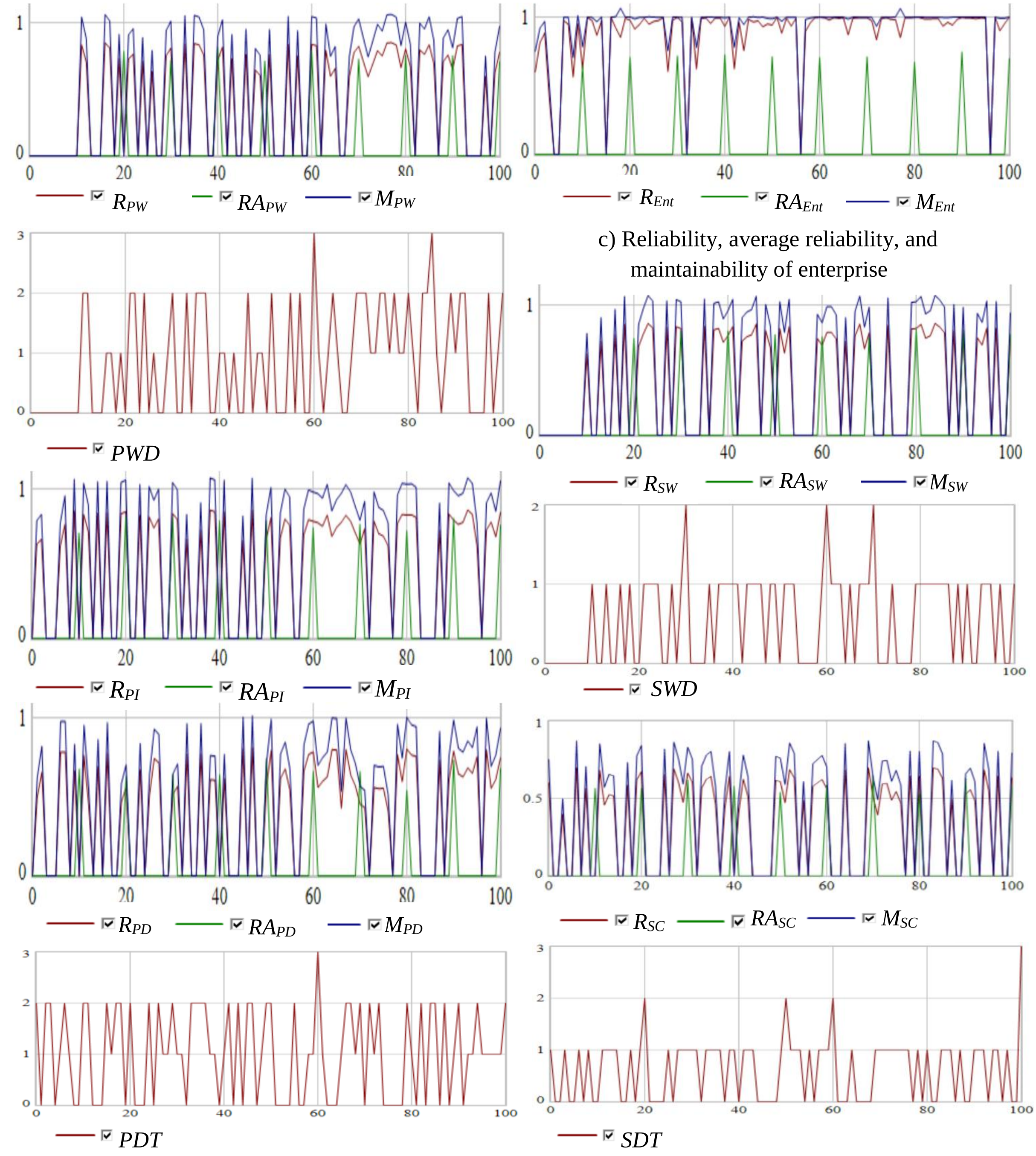


Figure 4. SFD of demand, reliability, average reliability, maintainability of services and enterprise



c) Reliability, average reliability, and maintainability of enterprise

a) Product demand and its reliability, average reliability, and maintainability

b) Service demand and its reliability, average reliability, and maintainability

Figure 5. SD simulation output *(T = 0* to *T = 100)*

To ensure that DM created is the correct representation of the real system (The enterprise in the case study) then the demands from SD simulation output (PDT and SDT) are compared with the actual ones by using statistical behavioral test (goodness-of-fit test). The test results are:

Table 2. SD simulation output ($T = 0$ to $T = 10$)

Variable	**Time (Day)**										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PDT	0	2	2	0	0	0	1	1	0	1	0
SDT	1	0	0	1	0	0	1	0	1	0	0
PWD	0	0	0	0	0	0	0	0	0	0	0
SWD	0	0	0	0	0	0	0	0	0	0	1
R_{PD}	0	0.497	0.657	0	0	0	0.782	0.782	0	0.666	0
R_{PI}	0	0.631	0.664	0	0	0	0.616	0.764	0	0.853	0
R_{SC}	0.601	0	0	0.398	0	0	0.698	0	0.565	0	0
R_{PW}	0	0	0	0	0	0	0	0	0	0	0
R_{SW}	0	0	0	0	0	0	0	0	0	0	0.626
R_{Ent}	0.601	0.814	0.885	0.398	0	0	0.975	0.949	0.565	0.951	0.626
RA_{PD}	0	0	0	0	0	0	0	0	0	0	0.677
RA_{PI}	0	0	0	0	0	0	0	0	0	0	0.706
RA_{SC}	0	0	0	0	0	0	0	0	0	0	0.565
RA_{PW}	0	0	0	0	0	0	0	0	0	0	0
RA_{SW}	0	0	0	0	0	0	0	0	0	0	0
RA_{Ent}	0	0	0	0	0	0	0	0	0	0	0.649
M_{PD}	0	0.621	0.821	0	0	0	0.977	0.978	0	0.833	0
M_{PI}	0	0.789	0.830	0	0	0	0.770	0.954	0	1.066	0
M_{SC}	0.751	0	0	0.498	0	0	0.871	0	0.706	0	0
M_{PW}	0	0	0	0	0	0	0	0	0	0	0
M_{SW}	0	0	0	0	0	0	0	0	0	0	0.783
M_{Ent}	0.751	0.920	0.970	0.498	0	0	0.999	0.999	0.706	1.011	0.783

- The mean absolute deviation, the mean square error, and the root mean square error of PDT, which have the values of 0.05, 0.05 and 0.223, respectively.
- The mean absolute deviation, the mean square error, and the root mean square error of SDT, which have the values of 0.04, 0.04, and 0.2 respectively.

These results indicate that the demand from simulation output and actual demands have a significant similarity.

4.4. Scenario

Scenario A (in Section 4.3) is the scenario that represents how the current system is operating. This scenario is used to compute the service performances of the enterprise, that is the reliability, maintainability, as well average reliability that affected to the demand. In order to show the effect of the time variable change on the other variables then the other scenarios should be specified in this SDS.

Therefore, the decrease in $STDF_i$, the decrease in meantime of $STDF_i$, the decrease in $MTRF_i$ (service time variables) from 90% until 60% are fixed as the next simulation scenario (B to M). The decrease is only up to 60% because if it continues then the simulation of DM cannot produce value. Twelve scenarios are presented as follows.

- Decreasing $STDF_i$ to 90% (Scenario B), 80% (Scenario C), 70% (Scenario D), and 60% (Scenario E).
- Decreasing meantime of $STDF_i$ to 90% (Scenario F), 80% (Scenario G), 70% (Scenario H), and 60% (Scenario I).
- Decreasing $MTRF_i$ to 90% (Scenario J), 80% (Scenario K), 70% (Scenario L), and 60% (Scenario M).

5. Result and discussion

The actual output of each scenario (B to M) is in the form of graphic (such in Fig.5). In order to conduct the analysis the simulation scenarios, the value in each variable is tabulated to the total (total value during simulation time), event number (number of occurrences during simulation time) and average (total value divided by the event number during simulation time). The tabulated values are arranged in Table 3.

Table 3. Summarized of scenario simulation output (A to M)

Variable		**Decrease *STDF***				**Decrease meantime of *STDF***				**Decrease of *MTRF***			
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
Total of demand													
PDT	101	101	96	99	102	101	102	100	94	101	98	94	94
PDT	63	63	61	61	62	63	63	63	63	63	60	60	60
PWD	88	88	87	89	92	88	89	90	87	88	86	84	84
SWD	55	55	57	57	58	55	55	56	57	55	53	53	53
Event number of demand													
PDT	64	64	60	60	60	64	64	60	58	64	64	63	63
PDT	58	58	55	55	55	58	58	53	59	58	57	58	58
PWD	55	55	52	52	52	55	55	55	52	55	55	54	54
SWD	52	52	51	51	51	52	52	48	54	52	51	52	52
Average of demand													
PDT	1.578	1.578	1.6	1.65	1.7	1.578	1.594	1.667	1.621	1.578	1.531	1.492	1.492
PDT	1.086	1.086	1.109	1.109	1.127	1.086	1.086	1.189	1.068	1.086	1.053	1.034	1.034
PWD	1.6	1.6	1.673	1.712	1.769	1.6	1.618	1.636	1.673	1.600	1.564	1.556	1.556
SWD	1.058	1.058	1.118	1.118	1.137	1.058	1.058	1.167	1.056	1.058	1.039	1.019	1.019
Event number of reliability													
R_{PD}	64	64	60	60	60	64	64	60	58	64	64	63	63
R_{PI}	64	64	60	60	60	64	64	60	58	64	64	63	63
R_{SC}	58	58	55	55	55	58	58	53	59	58	57	58	58
R_{PW}	55	55	52	52	52	55	55	55	52	55	55	54	54
R_{SW}	52	52	51	51	51	52	52	48	54	52	51	52	52
R_{Ent}	95	95	95	95	95	95	95	95	94	95	95	95	95
Event number of average reliability													
AR_{PD}	10	10	10	10	10	10	10	10	10	10	10	10	10
AR_{PI}	10	10	10	10	10	10	10	10	10	10	10	10	10
AR_{SC}	10	10	10	10	10	10	10	10	10	10	10	10	10
AR_{PW}	9	9	9	9	9	9	9	9	9	9	9	9	9
AR_{SW}	9	9	9	9	9	9	9	9	9	9	9	9	9
AR_{Ent}	10	10	10	10	10	10	10	10	10	10	10	10	10
Event number of maintainability													
M_{PD}	64	64	60	60	60	64	64	60	58	64	64	63	63
M_{PI}	64	64	60	60	60	64	64	60	58	64	64	63	63
M_{SC}	58	58	55	55	55	58	58	53	59	58	57	58	58
M_{PW}	55	55	52	52	52	55	55	55	52	55	55	54	54
M_{SW}	52	52	51	51	51	52	52	48	54	52	51	52	52
M_{Ent}	95	95	95	95	95	95	95	95	94	95	95	95	95
Average of reliability													
R_{PD}	0.655	0.738	0.83	0.937	1.058	0.723	0.8	0.801	0.821	0.626	0.592	0.548	0.548
R_{PI}	0.765	0.765	0.775	0.775	0.775	0.765	0.765	0.78	0.766	0.765	0.765	0.766	0.766
R_{SC}	0.58	0.58	0.578	0.578	0.578	0.58	0.58	0.56	0.564	0.58	0.581	0.583	0.583
R_{PW}	0.75	0.75	0.762	0.762	0.762	0.75	0.75	0.752	0.74	0.75	0.752	0.753	0.753
R_{SW}	0.78	0.78	0.772	0.772	0.772	0.78	0.78	0.749	0.763	0.78	0.78	0.778	0.778
R_{Ent}	0.935	0.938	0.93	0.935	0.939	0.938	0.941	0.924	0.925	0.934	0.932	0.93	0.93
Average of average reliability													
AR_{PD}	0.661	0.744	0.839	0.945	1.066	0.73	0.807	0.793	0.819	0.632	0.598	0.551	0.551
AR_{PI}	0.769	0.769	0.774	0.774	0.774	0.769	0.769	0.778	0.765	0.769	0.769	0.77	0.77
AR_{SC}	0.584	0.584	0.573	0.573	0.573	0.584	0.584	0.558	0.565	0.584	0.585	0.587	0.587
AR_{PW}	0.751	0.751	0.762	0.762	0.762	0.751	0.751	0.752	0.743	0.751	0.754	0.752	0.752
AR_{SW}	0.781	0.781	0.769	0.769	0.769	0.781	0.781	0.752	0.761	0.781	0.781	0.780	0.780
AR_{Ent}	0.704	0.722	0.741	0.764	0.790	0.719	0.736	0.724	0.729	0.698	0.692	0.682	0.682
Average of maintainability													
M_{PD}	0.818	0.923	1.037	1.171	1.322	0.904	0.999	1.001	1.027	0.782	0.740	0.685	0.685
M_{PI}	0.957	0.957	0.969	0.969	0.969	0.957	0.957	0.975	0.957	0.957	0.957	0.957	0.957
M_{SC}	0.725	0.725	0.723	0.723	0.723	0.725	0.725	0.7	0.705	0.725	0.726	0.729	0.729
M_{PW}	0.937	0.937	0.953	0.953	0.953	0.937	0.937	0.94	0.925	0.937	0.939	0.941	0.941
M_{SW}	0.975	0.975	0.965	0.965	0.965	0.975	0.975	0.937	0.954	0.975	0.975	0.973	0.973
M_{Ent}	0.977	0.978	0.972	0.972	0.973	0.977	0.978	0.968	0.97	0.977	0.976	0.976	0.976

Although the DM contains negative feedback, generally, the decrease of $STDF_i$ causes the increase in other variables in DM (see Fig.3). In scenario B to M, various levels of decrease in $STDF_i$, meantime of $STDF_i$, and $MTRF_i$ (from 90% to 60%) result in various effects (not just increase) in other variables in DM. The decrease in $STDF_i$ (Scenario B to E) causes no change to certain variables (event number of average reliability ($RA_{PD} = 10, RA_{PI} = 10, RA_{SC} = 10, RA_{PW} = 9, RA_{SW} = 9$ and $RA_{Ent} = 10$)), causes increase and decrease to certain variables (total of demand (PDT, SDT, PWD and SWD), average of reliability ($R_{PD}, R_{PI}, R_{SC}, R_{PW}$ and R_{SW}), average of average reliability ($RA_{PD}, RA_{PI}, RA_{SC}, RA_{PW}$ and RA_{SW}), and average of maintainability ($M_{PD}, M_{PI}, M_{SC}, M_{PW}$ and M_{SW})), and causes decrease to certain variables (number of demands (PDT, SDT, PWD and SWD), number of reliability ($R_{PD}, R_{PI}, R_{SC}, R_{PW}$ and R_{SW}), and number of maintainability ($M_{PD}, M_{PI}, M_{SC}, M_{PW}$ and M_{SW})).

Based on scenario F to I (from 90% to 60%), the decrease in the meantime of $STDF_i$ causes no change to certain variables (event number of average reliability ($RA_{PD} = 10, RA_{PI} = 10, RA_{SC} = 10, RA_{PW} = 9, RA_{SW} = 9$ and $RA_{Ent} = 10$)), causes increase and decrease to certain variables (event number of demand, event number of reliability, event number of maintainability, average of reliability, average of average reliability, average of maintainability), and causes increase to certain variables (total of demand and average of demand).

Based on scenario J to M (from 90% to 60%), the decrease in the of $MTRF_i$ causes no change to certain variables (event number of average reliability), causes increase and decrease to certain variables (average of reliability, average of average reliability, and average of maintainability), and causes decrease to certain variables (total of demand, event number of demand, average of demand, event number of reliability, and event number of maintainability).

6. Conclusion and future work

This article has proposed the SDS that can be used to compute reliability, average reliability, and maintainability of individual service and enterprise as well demand over time. DM forms a closed system (there are no disconnected variables) containing negative feedbacks that are formed by the relationship between $STDF_i$ and R_i. Although there are negative feedbacks (based on scenario simulation (B to M)), this SDS results shows that the decrease in time variables ($STDF_i$, meantime of $STDF_i$, and $MTRF_i$) have various effects (decrease, increase or no change) to other variables (demand, reliability, average reliability, and maintainability).

In the future work, the DM that created can be developed to a new model that can be used to compute availability, supportability, as well as cost. That work aims to compute a number of reliable services, service capability to achieve a reliability target, resources required, and a risk that can be avoided due to the reliability achieved.

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