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The Handling of "Waiters" Problem by Telecommunication Service Provider: A System Dynamics Approach

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Abstract

The queueing theory has been used by academicians and practitioners to solve supply chain problems over the years. Here, we propose a system dynamics approach and queuing theory parameters to discover the best method to handle the (supply chain) "Waiters" problem via a telecommunication service provider. We developed more than one system dynamics model and introduced the following parameters: the number of times information about registered waiters and the number of days required for procuring and commissioning the (telecommunication) ports are collected in a month. We found the number of waiting times for the customers is reduced and improved when the above-mentioned first parameter is performed more frequently (*i.e.,* more than once).

Keywords

Queuing Theory, Supply Chain, System Dynamics Methodology

1. Introduction

Commonly or frequently used by academicians and practitioners, queuing models find the balance between the number of servers and the waiting time of the customers. For example, if the number of servers is high, the waiting time (cost of customer idle time) will be low. The said models find the optimum number of customer order service points (servers) to lower the business cost. Hillier *et al.* [1] considered the following as a queuing problem: finding the number of service facilities, the efficiency of the servers, and the number of servers of different types at the service facilities. Suri [2] suggested using the queuing theory to solve supply chain problems. Christopher [3] changed the term "Chain" in supply chain to "Network", likening supply chain to a pipeline of physical and informational flows between suppliers and customers. This pipeline works like a process of distributed activities being carried out. Aitken [4] defined supply chain as a network of connected and inter-dependent organisations mutually and co-operatively working together to control, manage and improve the flow of materials and information from supplier to end-users. Heskett [5] used the supply chain theory in logistics. According to Bhaskar *et al.* [6], after the items are served by the last node of, for example, Stage 1 of the queueing network, the items will proceed and be serviced by node of Stage 2 of the queueing network; this gives the minimum response. The optimisation of the queueing network is defined by the average number of items that can be delivered with minimum response. Al-Amin Molla [7] exhibited that the queueing model managed to solve the problems of customers having to wait in a long queue to be served by a restaurant called Suruchi. Woensel *et al.* [8] presented different analytics queuing models for traffic on road networks. They showed that developed published methodologies (mainly single node oriented) could be extended towards queuing networks. Furthermore, they studied the impact of buffer sizes when comparing different queuing network methodologies. Finally, they suggested an analytical application tool to facilitate the optimal positioning of the counting points on a highway.

Hamdi *et al.* [9] reviewed the essential features of the Transmission Control Protocol mechanism. Transmission Control Protocol, defined as internet protocols for congestion and traffic control, controls the rate of information received by the transportation layer using a congestion control system to ensure that the transmitter does not overload the network. They showed two main classes of the existing router queue management system: Adaptive Random Early Detection and Random Early Detection. Their studies showed that Adaptive Random Early Detection performed better than Random Early Detection. Iversen's [10] chapter titled "Markovian queueing systems" considers traffic to a system with n identical servers, full accessibility, and a queue with an infinite number of waiting positions. Two traffic models are considered, namely: 1) Poisson arrival process (an infinite number of sources) and exponentially distributed service times (an essential queueing system called Erlang's delay system, where the carried traffic equals to offered traffic since no customers are blocked); 2) A limited number of sources and exponentially distributed service times (Palm's machine repair model, widely applied for example dimensioning of computer systems and terminal systems). Osahenvemwen *et al.* [11] aimed to achieve effective utilization (management) of a queue in service delivery in mobile communication network call centres and other relative public infrastructures. They developed analytical mathematical models of queue theory based on Markov chain analysis of continuous-time and discrete space to model the effective utilization of mobile call centres (public infrastructures) based on arrival calls (rate of subscribers) and service rate. They observed an increase in capacity, such as an increase in the number of staff (servers), would lead to underutilization of the system and an increase in idleness time from the team. On the other hand, low capacities due to the low number of staff will increase the customer's waiting time. Bose [12] analysed various models of single server queueing systems with necessary implementation using Microsoft Excel and Matlab software. A virtual telecommunication system implemented using Microsoft Excel was considered, along with an advanced simulation of the queuing system and mathematical tools to analyse them. Finally, they showed the use of these models through various communication applications.

In this article (divided into the methodology, results, and discussion), we used the system dynamics approach and queuing theory parameters (e.g., the number of times in a month, information about registered waiters were collected, and the number of days for procuring and commissioning the ports) to find the best way of handling (Supply Chain) "Waiters" problem. Here, "Waiters" is defined or best described by the following example: *A customer visits telecommunication service provider "A" outlet and subscribes to "A" product related to internet connectivity. "A" will check through their system whether there are ports available at "A" telecommunication "exchange" nearest to the customer's address. The ports are essential to connect the customer's device (e.g., laptop and desktop) and the internet. If there are none, the customer will be placed under a waiting list (labelled as "Waiters"). The number of days they have to wait depends on how fast "A" could provide the much-needed ports.* Note that there are cases where the customers have to wait weeks, months, and even years to get internet connectivity. The "Waiters" problem is solved when the number of waiting times, and consequently waiters, is reduced considerably.

2. Methodology

System dynamics, by Forrester [13], is defined as a methodology for understanding how things change over time. Stock, represented by A in **Figure 1**, is an element that accumulates and depletes over time. Flow, represented by B and C, is the rate of change in a stock. Link defines dependency between the elements of a stock and flow diagram, and Auxiliary, represented by ALPHA (α), COUNTER (t), and BETA (β), is used to define some intermediate concepts. Positive feedback loops enhance or amplify changes, which tends to move a system away

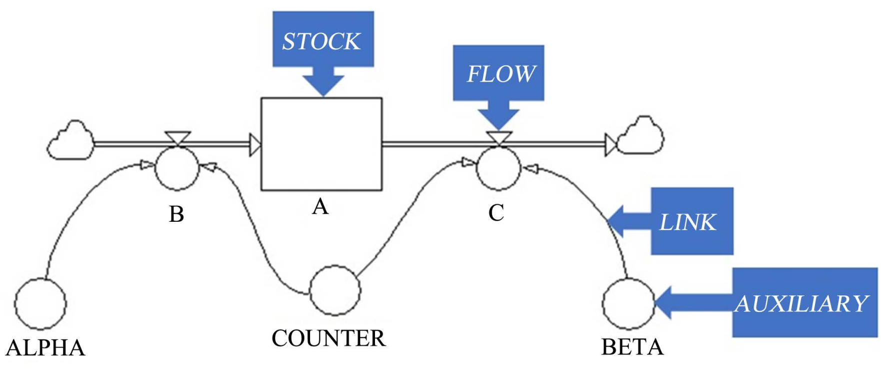


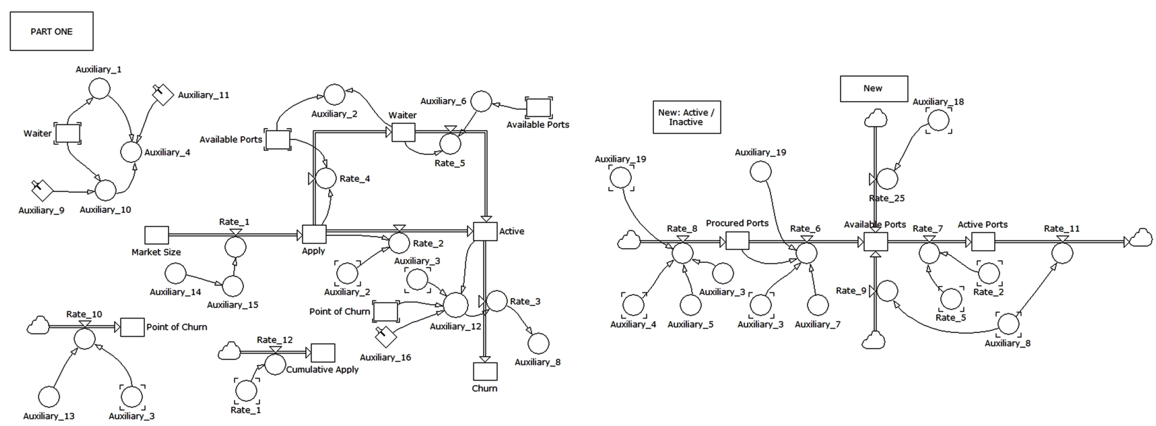
Figure 1. A typical system dynamics model.

from its equilibrium state and make it more unstable. Negative feedback loops dampen or buffer changes, which tends to hold a system to some equilibrium state making it more stable. Examples of its applications can be found in Yusoff [14] and Yusoff [15].

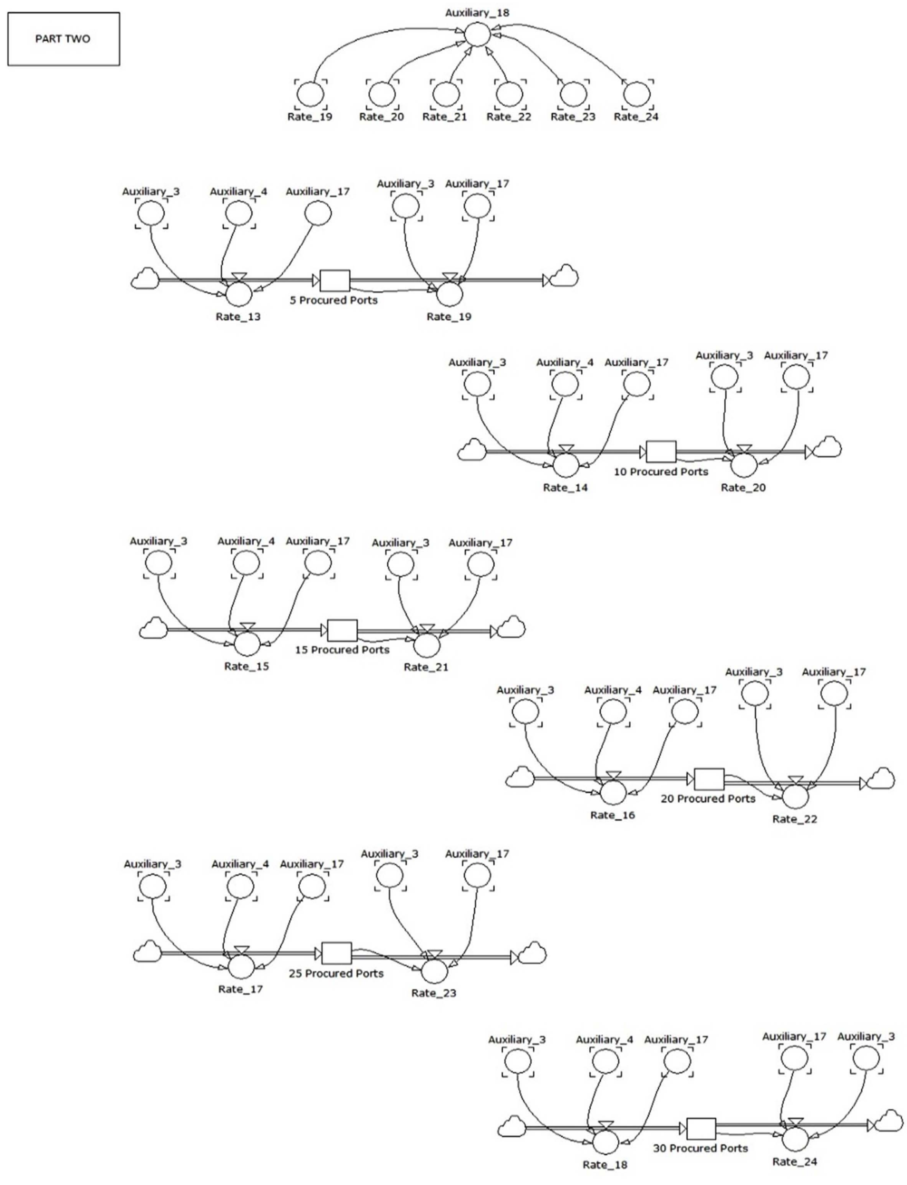
Based on **Figure 1**, the rate of input B to stock A and output C from stock A are represented by $B = \alpha t$ and $C = \beta t$, respectively where $\alpha > \beta$, $t = 0,1,2,3,\cdots$. The behaviour of stock A is represented by $A = (\alpha - \beta)\frac{t^2}{2}$, $t = 0,1,2,3,\cdots$.

Giving birth to "*Waiters*" *Model 1 and Model 2*, as shown in **Figure 2**; system dynamics can be applied to any area (e.g., district, region and state) and (telecommunication) product. The said models were built using, apart from information given in **Introduction**, *Powersim* software; a brief description is provided below.

- Customers under "Apply" are converted into "Active" when ports (to serve them) are available. They are converted into "Waiter" when ports are not available.
- Customers under "Active" are converted into "Churn" when they are migrated to competitors. They would migrate after subscribing for "x" number of months (or years).
- "Available Ports" are converted into "Active Ports" when they are serving customers.
- One port "serves" one customer.
- "Market size" is fixed at 100,000.
- Application is fixed at normal (mean = 10; standard deviation = 5) daily. This statistical distribution can be replaced by studying the historical data of applications for the selected area.
- The simulation period is fixed at one year (30 days per month). Saturday, Sunday, and holidays are not included in the said models.
- Except for "market size" at the beginning (or t = 0), all levels (or reservoirs) are fixed at 0.
- The following parameters are skipped (*i.e.*, not included) in Model 1: drop-list, quality of service (QoS) and quality of experience (QoE). The first parameter is related to "Waiter" and the rest are related to "Churn".
- The number of procured ports could be "Fixed (×1000)" or "Percentage" at "Auxiliary_11". If the latter (*i.e.*, "Percentage") is chosen, the percentage could be changed at "Auxiliary_9" (*i.e.*, 0, 10, 20, … 100). For example, number of procured ports = 1.1 × "Waiter" if "Auxiliary_9" equals to 10 is chosen.
- Percentage of churn (against "Active" customers) for a specific simulation time could be changed at "Auxiliary_16" (*i.e.*, 0, 1, 2, … 100). For example, at time t, Churn = (1/100) × "Active" if 1 percent is chosen. This percentage (as well as the number of incidents) could be replaced by studying the historical data of churn for the selected area.



(a)



(b)

Figure 2. (a) and (b) represent "*Waiters*" *Model 1* and "*Waiters*" *Model 2*.

- The number of incidents is fixed at one and after 6 months of simulation time (*i.e.*, July onwards).
- "Churn" will impact on the following parameters: "Active", "Available Ports" and "Active Ports".

"Waiters" Model 1: The number of procured ports depends on number of waiters registered on the 30th of each month. This value could be replaced by studying the current process employed by the organisation. The procured ports will be made available (or commissioned) on the 15th of the following month (*i.e.,* "Procured Ports" are converted into "Available Ports"). This value could be replaced by studying the current process employed by the organisation.

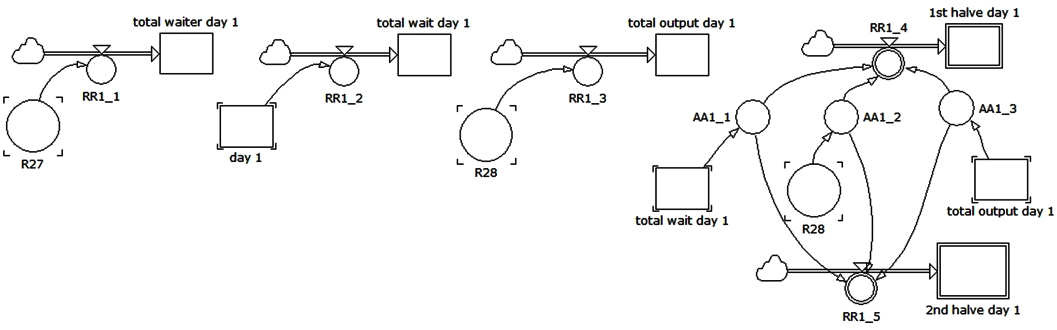
"Waiters" Model 2: The number of procured ports depends on number of waiters registered on 5th, 10th, 15th, 20th, 25th, 30th of each month, which is six times more frequent than "Waiters" Model 1. These values could be replaced by studying the current process employed by the organisation. The procured ports will be made available (or commissioned) after 10 days from each of the date mentioned above (*i.e.*, "Procured Ports" are converted into "Available Ports"). Note that, 5th, 10th, 15th, 20th, 25th, 30th are "independent" to one another (or "independent" events). These values could be replaced by studying the current process employed by the organisation.

To find the number of days, the customers on the waiting list have to wait until the services they applied are available. Modifications were made on "Waiters" *Model 1* and *Model 2*; refer to **Figure 3**. Due to limitations of the system dynamics approach, we decided to focus on the first 45 simulation days. Limitations here refer to stock characteristics, defined as an element that accumulates and depletes over time, including the inability to "tag" every customer. Therefore, we must create a unique (system dynamics) model with a "tagging" mechanism.

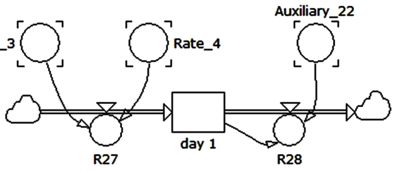
The results for the rest of the simulation days are assumed to be the same as the first 45 simulation days. Note that **Figure 3** stocks labelled "1st halve day 1" and "2nd halve day 1" are created to capture the behaviour as exemplified in **Figure 4**. This behaviour occurs when customers under the waiting list for the given (registered) day are converted into "Active" customers in two phases instead of the usual one phase. For each percentage, iteration and all 45 simulation days, μ and σ, representing the number of waiting days, are calculated. The symbols μ and σ represent average and standard deviation for the given event (or scenario). For each percentage and all iterations, *Average* and *Standard Deviation* are calculated for each μ and σ.

Brief explanation about "*Waiters*" *Model 1* behaviours:

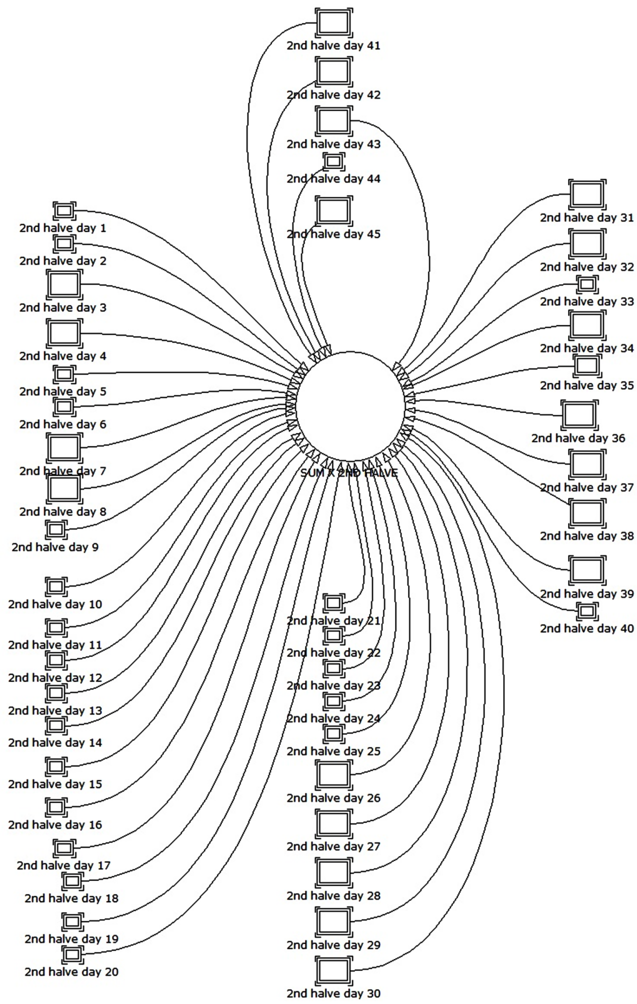
"*Waiters*" *Model 1*: *number of ports to be procured equals to* (*1* + *percentage*) *multiplied by the number of waiters registered on the 30*th *of each month* (*i.e.*, *percentage can be assigned with a value between 0 and 100*). *They are converted into available ports on the 15*th *of the following month. In the meantime*, *new waiters will be registered* (*adding to the existing waiters*) *between 1*st *and 15*th *of the following month due to available ports being equal to zero* (*0*). *Waiters on*



(a)



(b)



(c)

Figure 3. (a), (b) and (c) represent some of the modifications made in "*Waiters*" *Model 1* and *Model 2*.

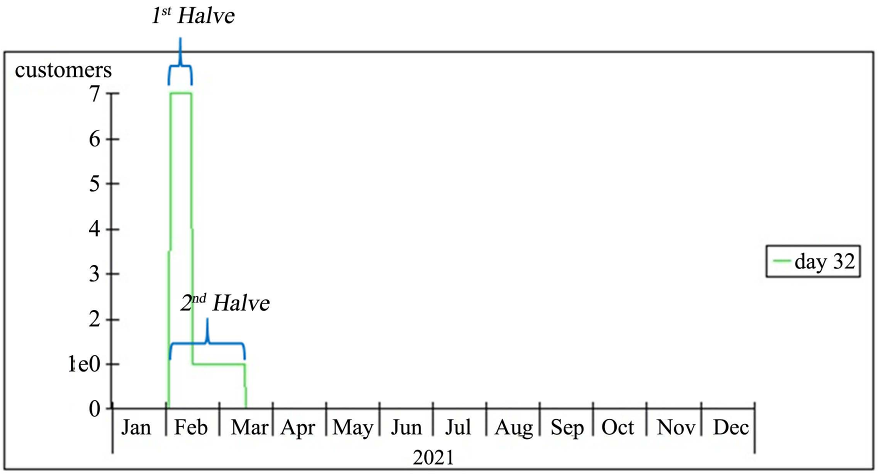


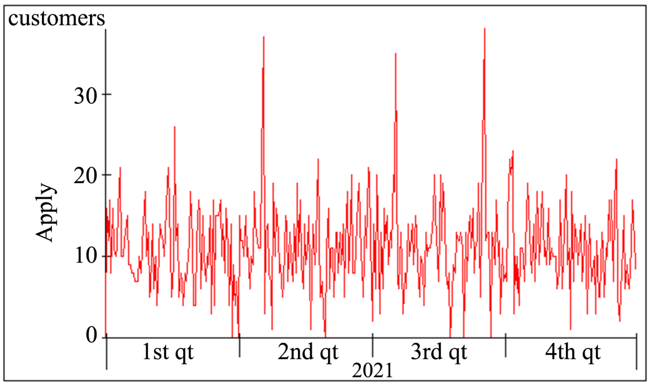
Figure 4. "1st Halve" and "2nd Halve" in the graph represent "1st Halve day 32" and "2nd Halve day 32" stocks (replacing "day 1" with "day 32" in Figure 3(a)).

the 30th of the previous month will be converted (into active customers) first. If there are available ports, waiters registered between 1st and 15th of the following month and new applications (after 15th of the following month) will be converted into active customers (i.e., the said process continues until available ports equal to zero and new applications are converted into waiters). If available ports are equal to zero, new applications (after 15th of the following month) will be converted into waiters and only limited number of waiters (depending on the value of percentage) between 1st and 15th of the following month will be converted into active customers.

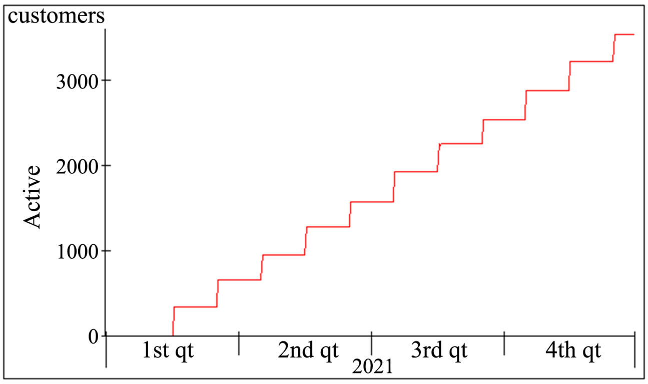
Note that the same explanation can be used to describe "*Waiters*" *Model 2* behaviours.

3. Results

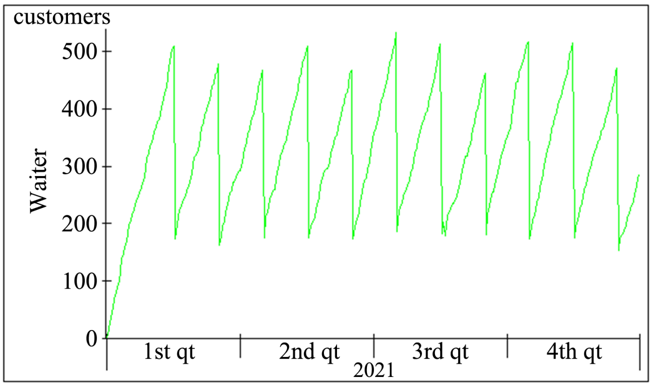
"*Waiters*" *Model 1* ("Auxiliary_11", "Auxiliary_9" and "Auxiliary_16" equal to Percentage, 0 and 1, respectively) was executed where Figure 5(a) shows normal (10;5) behaviour for "Apply". Note that there are days "Apply" equals to zero (0). Figure 5(b) shows a "step-shaped" behaviour for "Active". The said behaviour is repeated until the end of simulation time. Note that on average, *90.56%* (with standard deviation equalling to *0.64*) of "Apply" customers are converted into "Active". Figure 5(c) shows a "left-triangle-shaped" behaviour (*i.e.*, "Available Ports" are not equal to zero, 0, and serve only a limited number of customers). The said behaviour repeated until the end of simulation time. Note that except at the beginning of simulation time, "Waiter" equals to a non-zero value until the end of simulation time. Figure 5(d) shows a "step-shaped" behaviour for "Churn" (impacting on Figure 5(e) and Figure 5(f)). Figure 5(e) shows a "spike-shaped" behaviour for "Available Ports". The said behaviour repeated until the end of simulation time. "Available Ports" are not available until "Procured Ports" conversion; refer to Figure 5(g). The "not available" simulation period is *longer*. Figure 5(f) shows "Active Ports" behaves in similar


customers
Apply
0
10
20
30
1st qt
2nd qt
3rd qt
4th qt
2021

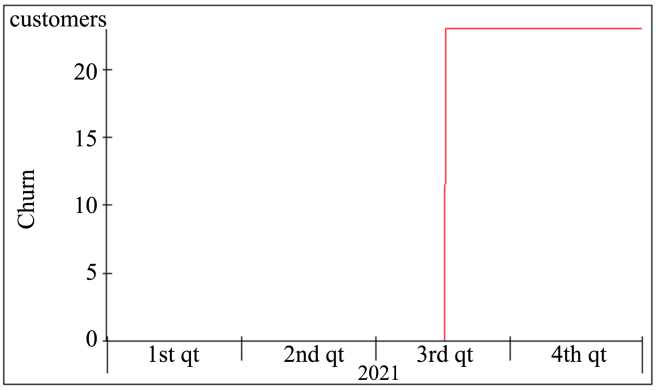
(a)


customers
Active
0
1000
2000
3000
1st qt
2nd qt
3rd qt
4th qt
2021

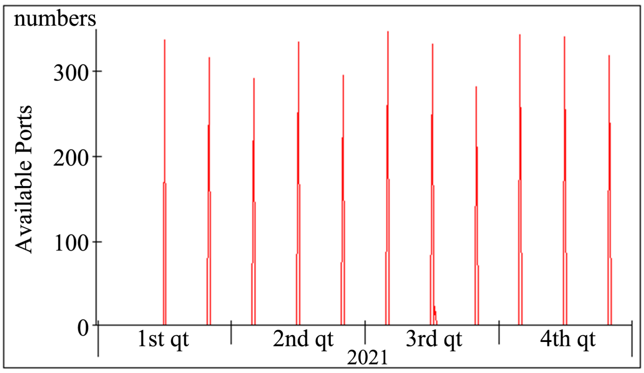
(b)


customers
Waiter
0
100
200
300
400
500
1st qt
2nd qt
3rd qt
4th qt
2021

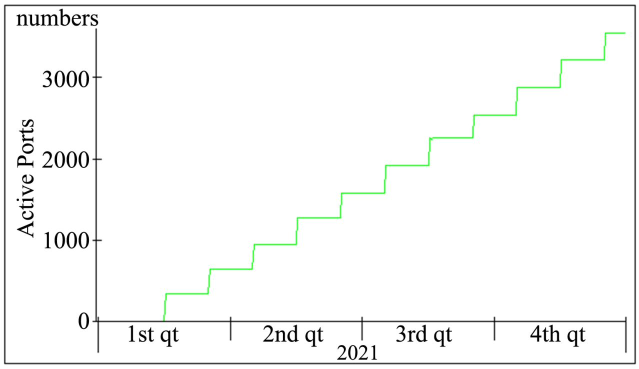
(c)


customers
Churn
0
5
10
15
20
1st qt
2nd qt
3rd qt
4th qt
2021

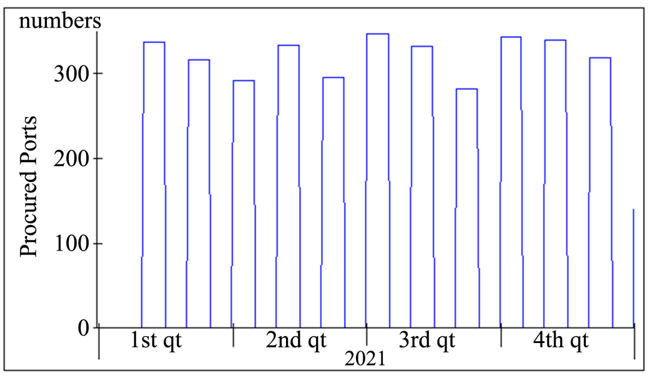
(d)



(e)



(f)



(g)

Figure 5. (a) "Apply", (b) "Active", (c) "Waiter", (d) "Churn", (e) "Available Ports", (f) "Active Ports" and (g) "Procured Ports" versus simulation time for "*Waiters*" *Model 1*.

fashion as "Active"; refer to Figure 5(b). Figure 5(g) shows a "column-shaped" behaviour for "Procured Ports". The decreasing trend occurs when "Procured Ports" are converted into "Available Ports". The said behaviour repeated until the end of simulation time. Note that due to behaviour of "Apply" in Figure 5(a), "Procured Ports" fluctuated above 200. Figure 6 shows the combination (as well as their dependencies) of Figure 5(c), Figure 5(e), and Figure 5(g).

The results (of "Apply" converted into "Active") for "*Waiters*" *Model 1*; "Auxiliary_9" can be found in Table 1(a) (note that "Average" increases as "Auxiliary_9" increases); cumulative "Apply" can be found in Table 1(b).

Table 1. "Auxiliary_9", average and Standard deviation for "*Waiters*" *Model 1*: (a) "Apply" converted into "Active" and (b) Cumulative "Apply".

(a)

"Auxiliary_9"	*Average (%)*	*Standard deviation (%)*
10	*91.32*	*0.91*
20	*91.73*	*0.89*
30	*92.70*	*0.76*
40	*93.01*	*0.87*
50	*93.01*	*0.96*
60	*93.90*	*0.57*
70	*93.80*	*1.40*
80	*94.98*	*1.11*
90	*95.41*	*1.27*
100	*96.45*	*2.14*

(b)

"Auxiliary_9"	*Cumulative "Apply"*	
	Average	*Standard deviation*
0	*3806.96*	*82.85*
10	*3820.88*	*112.93*
20	*3812.72*	*85.69*
30	*3811.44*	*96.41*
40	*3801.44*	*82.24*
50	*3817.04*	*119.50*
60	*3788.48*	*101.37*
70	*3809.36*	*109.36*
80	*3795.32*	*124.68*
90	*3795.08*	*73.99*
100	*3795.88*	*100.64*

Figure 7 shows the combination (as well as their dependencies) of "Waiter", "Available Ports" and "Procured Ports" when "Auxiliary_9" equals to 100. Figure 8 shows "Waiter" behaviour when "Auxiliary_9" equals to **(a) 20**, **(b) 40**, **(c) 60**, **(d) 80** and **(e) 100**. Note that the number of waiters equals to zero (0) as "Auxiliary_9" increases. Figure 7 and Figure 8 show one of many simulations executed using the "Waiters" *Model 1*.

Table 2 shows number of days (out of 361 simulation days) "Waiters" are equal to zero (converted into percentage). *The bigger the percentage, the shorter the time spent by the customers under the waiting list.*

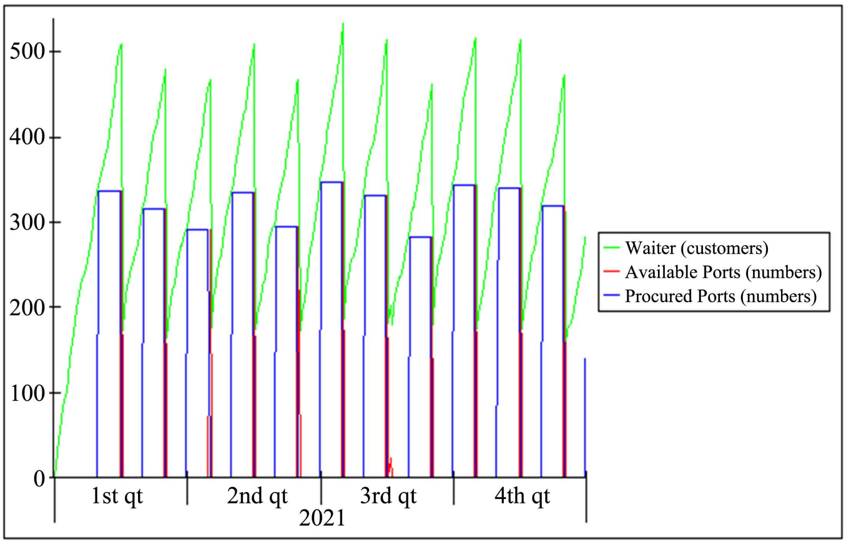


Figure 6. "Waiter", "Available Ports" and "Procured Ports" graphs are combined for "*Waiters*" *Model 1* when "Auxiliary_9" equals to zero (0).

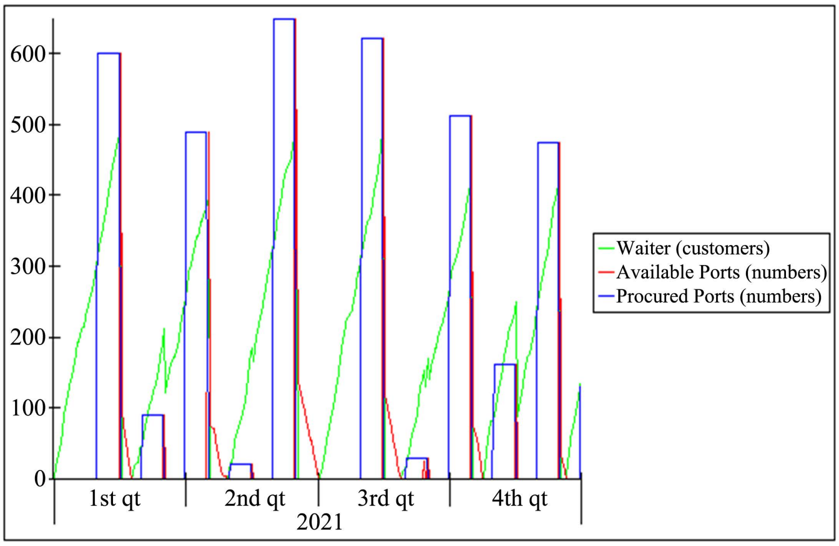
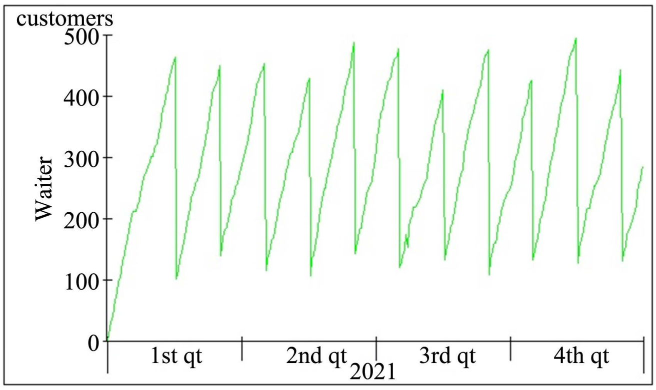


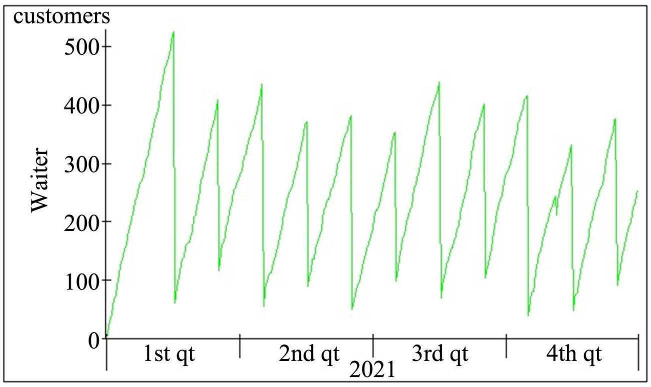
Figure 7. "Waiter", "Available Ports" and "Procured Ports" graphs are combined for "*Waiters*" *Model 1* when "Auxiliary_9" equals to 100.

Table 2. "Auxiliary_9", average and standard deviation for "*Waiters*" *Model 1*: number of days for "Waiters" are equal to zero.

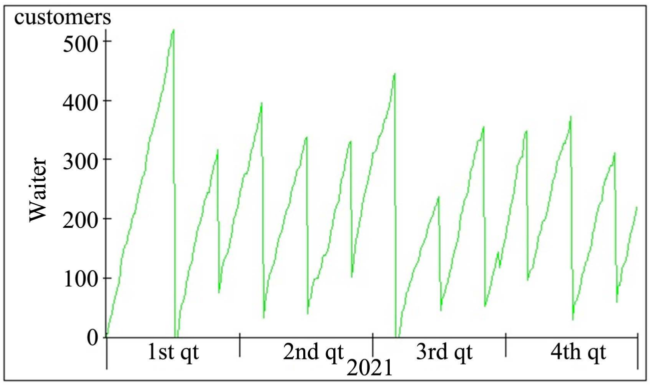
"Auxiliary_9"	*Average (%)*	*Standard deviation (%)*
0	*0.30*	*0.08*
20	*0.28*	*0.00*
40	*0.30*	*0.11*
60	*1.42*	*0.92*
80	*6.45*	*2.98*
100	*19.46*	*4.63*


customers
500
400
300
200
100
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

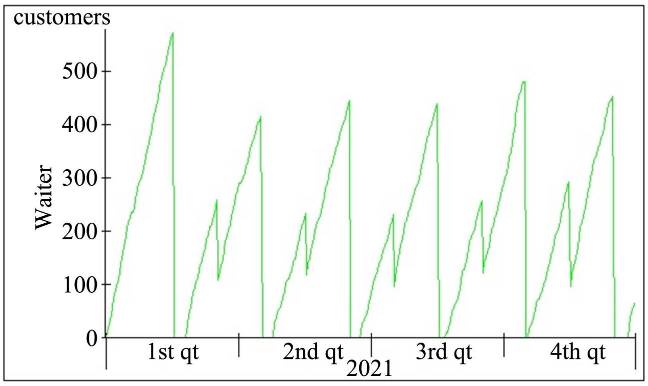
(a)


customers
500
400
300
200
100
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

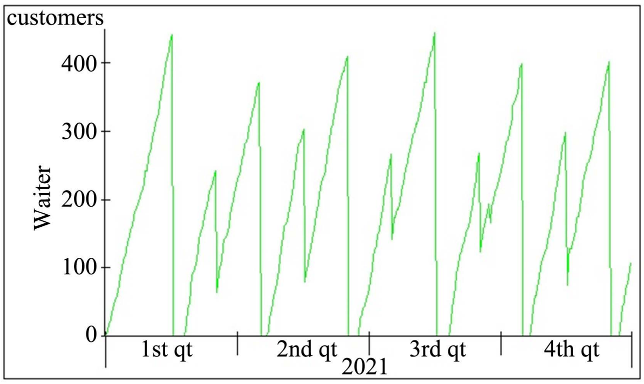
(b)


customers
500
400
300
200
100
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

(c)


customers
500
400
300
200
100
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

(d)



(e)

Figure 8. "Waiter" versus simulation time for "*Waiters*" *Model 1* when "Auxiliary_9" equals to (a) 20, (b) 40, (c) 60, (d) 80 and (e) 100.

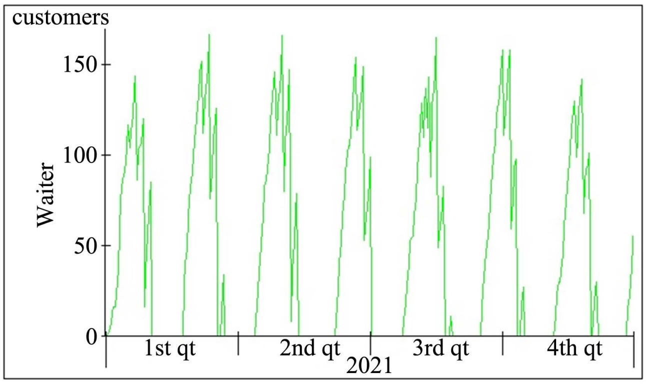
Table 3 shows the number of waiting days for the given "Auxiliary_9" for "*Waiters*" *Model 1.* Note that the number of waiting days decreases (as well as stabilises) as "Auxiliary_9" increases. For example, the *average* μ and σ (waiting days) when "Auxiliary_9" equals to *100* are *22.5* and *13.08*, respectively.

"*Waiters*" *Model 2* was executed where **Figure 9** shows "Waiter" behaviour when "Auxiliary_9" equals to **(a) 0**, **(b) 20**, **(c) 40**, **(d) 60**, **(e) 80**, and **(f) 100**. **Figure 9** shows one of many simulations executed using "*Waiters*" *Model 2. The gaps between non-zero waiters are observed* (*or displayed*), *although* "Auxiliary_9" *equals to zero* (*0*). *The gaps between non-zero waiters are becoming wider when changing the* "Auxiliary_9" *from 0 to 100.* **Table 4(a)** shows percentage of "Apply" converted into "Active", and **Table 4(b)** shows number of days (out of 361 simulation days) "Waiters" are equal to zero (converted into percentage). Notice that the percentage of "Apply" converted into "Active" exhibits an *upward* trend. A similar trend is observed for the percentage of (simulation) days "Waiters" are equal to zero (for example, "Waiters" are equal to zero, on average, 70.94% of simulation days when "Auxiliary_9" equals to 100 is selected). *The bigger the percentage*, *the shorter the time spent by the customers under waiting list.*

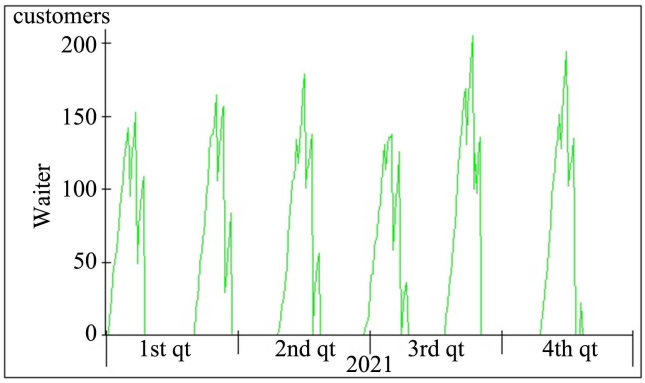
Table 5 shows the number of waiting days for the given "Auxiliary_9" for "*Waiters*" *Model 2.* Note that the number of waiting days decreases (as well as stabilises) as "Auxiliary_9" increases. For example, the *average* μ and σ (waiting days) when "Auxiliary_9" equals to *100* are *7.73* and *2.99*, respectively.

4. Discussion

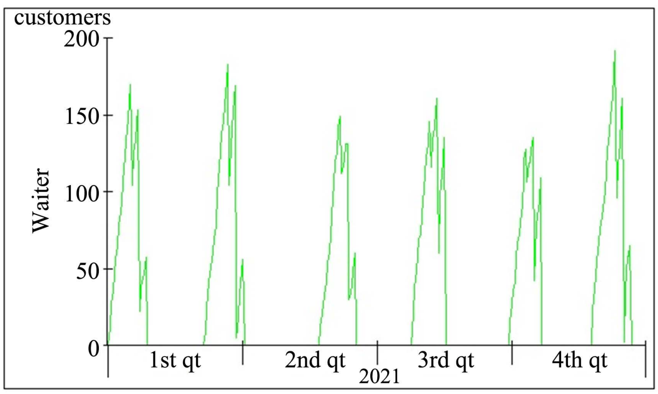
A system dynamics approach was used to develop "*Waiters*" *Model 1* and *Model 2* (consisting of hundreds of equations), with the main objective to find the best way of handling the "Waiters". Main characteristics of "*Waiters*" *Model 1* and *Model 2* are the number of times in a month the information about registered waiters is collected: it is collected once for "*Waters*" *Model 1* and (maximum) 6 times for "*Waiters*" *Model 2*. Results from information collected 2, 3, 4 and 5


customers
150
100
50
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

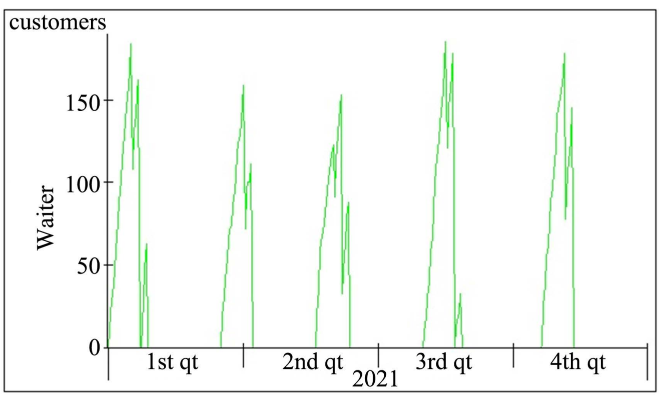
(a)


customers
200
150
100
50
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

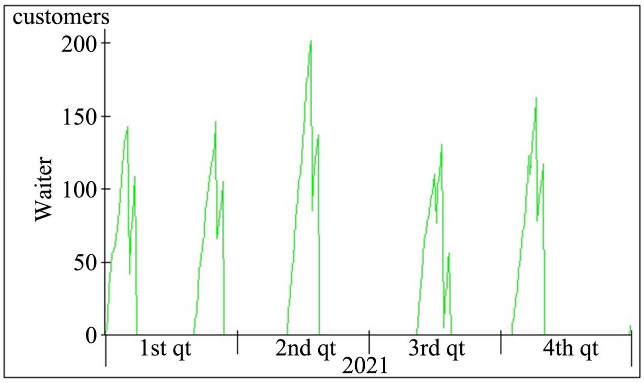
(b)


customers
200
150
100
50
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

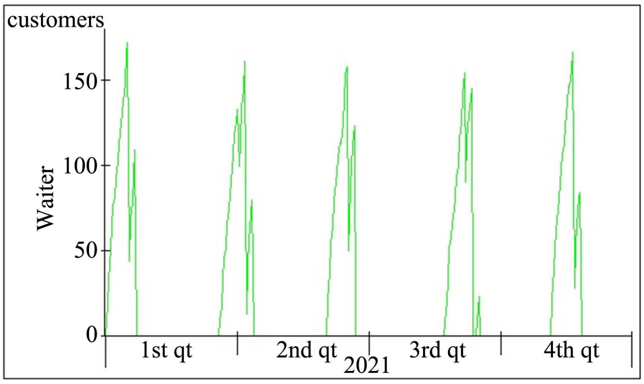
(c)


customers
150
100
50
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

(d)



(e)



(f)

Figure 9. "Waiter" versus simulation time for "*Waiters*" *Model 2* when "Auxiliary_9" equals to (a) 0, (b) 20, (c) 40, (d) 60, (e) 80 and (f) 100.

Table 3. "Auxiliary_9", μ, σ, average, and standard deviation for "*Waiters*" *Model 1*: number of waiting days.

"*Auxiliary_9*"		*Average*	*Standard deviation*
0	μ	*31.74*	*0.39*
	σ	*8.07*	*0.41*
20	μ	*28.17*	*0.64*
	σ	*9.1*	*0.36*
40	μ	*24.29*	*1.34*
	σ	*11.17*	*0.77*
60	μ	*22.27*	*0.39*
	σ	*12.41*	*0.19*
80	μ	*22.14*	*0.28*
	σ	*12.5*	*0.24*
100	μ	*22.55*	*0.38*
	σ	*13.08*	*0.57*

Table 4. "Auxiliary_9", average and standard deviation for "*Waiters*" *Model 2*: (a) "Apply" converted into "Active" and (b) number of days "Waiters" are equal to zero.

(a)

"*Auxiliary_9*"	*Average* (%)	*Standard deviation* (%)
0	*97.26*	*2.12*
20	*97.54*	*1.88*
40	*98.28*	*1.58*
60	*97.50*	*1.53*
80	*97.97*	*1.44*
100	*98.93*	*0.20*

(b)

"*Auxiliary_9*"	*Average* (%)	*Standard deviation* (%)
0	*48.04*	*1.84*
20	*56.66*	*2.09*
40	*60.51*	*1.15*
60	*65.64*	*2.56*
80	*68.74*	*1.74*
100	*70.94*	*0.88*

Table 5. "Auxiliary_9", μ, σ, average and standard deviation for "*Waiters*" *Model 2*: number of waiting days.

"*Auxiliary_9*"		*Average*	*Standard deviation*
0	μ	*8.23*	*0.40*
	Σ	*3.55*	*0.23*
20	μ	*8.38*	*0.41*
	σ	*3.07*	*0.43*
40	μ	*7.75*	*0.47*
	σ	*3.36*	*0.37*
60	μ	*7.8*	*0.44*
	σ	*3.29*	*0.33*
80	μ	*7.69*	*0.52*
	σ	*3.22*	*0.33*
100	μ	*7.73*	*0.45*
	σ	*2.99*	*0.12*

times a month, about registered waiters, are not included in this article. Other characteristics are: 1) the number of days for procuring (and commissioning) the ports; "*Waiters*" *Model 1* is fixed at 15 days and "*Waiters*" *Model 2* is fixed at

10 days for procuring (and commissioning) the ports and 2) "Auxiliary_9", one of the components used in deriving the number of procured ports, is fixed throughout the simulation time. The changing of "Auxiliary_9" over time is reserved for future research works.

"*Waiters*" *Model 1* and *Model 2* were executed where both models show, and irrespective of "Auxiliary_9" used, more than 90% of "Apply" converted into "Active". The said models' number of days where "Waiters" are equal to zero when "Auxiliary_9" equals to 100 are 19.46% and 70.94%, respectively. Both models depict an increasing trend for number of days "Waiters" are equal to zero when "Auxiliary_9" increases. *Model 1* starts 0.30%, whereas *Model 2* starts at 48.04%. *The bigger the percentage*, *the shorter the time spent by the customers under waiting list*. The average number of waiting days (represented by μ) for *Model 1* and *Model 2* when "Auxiliary_9" equals to 100 are 22.55 days and 7.73 days, respectively. Both models depict a decreasing trend for duration (or average number of waiting days) when "Auxiliary_9" increases; *Model 2* exhibits a much shorter duration (hence, superior results) than the former.

Note that there are two ways of procuring the ports: 1) through a yearly business plan, based on forecasted demand for the coming years and selected area; return over investment (ROI) would be impacted, and revenue cannot be generated from oversupply of ports (especially ports that are under-utilised); on the other hand, undersupply of ports will "create" waiters (except if more monies are requested for procuring extra or additional ports) and 2) based on the current demand, as highlighted in this article.

The following parameters are not included in the said models: 1) internal processes for procuring the ports that require getting approval from working committees, as highlighted by Yusoff [15] and 2) customers under the waiting list who decided to cancel their subscriptions (they are placed under "Drop" list).

If "*Waiters*" *Model 1* and *Model 2* are executed "live", 1) number of working days equals to five (*i.e.,* from Monday till Friday), 2) for "*Waiters*" *Model 1*, information about registered waiters is collected on the last working day of each month; 15 (or 10) working days are required to procure (and commission) the ports; *Team 1* is in charge of collecting the information about registered waiters, as well as procuring (and commissioning) the ports and 3) for "*Waiters*" *Model 2*, information about registered waiters is collection on the last working day of each week; 10 working days are required to procure (and commission) the ports; *Team 1* is in charge of collecting the information about registered waiters, and *Team 2* and *3* are in charge of procuring (and commissioning) the ports, thus ensuring there's no overlapping of workloads.

In both models, the percentage of "Churn" could be changed and the number of incidents is limited to only one from July onwards; it impacted "Active", "Available Ports" and "Active Ports" as either a small dent or a lump in the graphs. Details of "*Waiters*" *Model 1* numerical example and "*Waiters*" *Model 1* ("Fixed (×1000)", 1) can be found in **Appendix A**. There are other activities involved in establishing a connection between a customer's device (e.g., laptop and desktop) and the internet, for example, installing fibre cables to connect (the nearest) telecommunication "exchange" to the customer's address or house. The said activities, which may require more than 10 working days to complete, are reserved for future research works.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Hillier, F. and Lieberman, G. (2005) Introduction to Operation Research. 8th Edition, McGraw Hill, New York.

[2] Suri, R. (1998) Quick Response Manufacturing. Productivity Press, Portland.

[3] Christopher, M. (2005) Logistics and Supply Chain Management. 3rd Edition, Prentice Hall Inc., Englewood Cliffs.

[4] Aitken, J. (1998) Supply Chain Integration within the Context of a Supplier Association. Ph.D Thesis, Cranfield University, Cranfield.

[5] Heskett, J.L. (1977) Logistics: Essential to Strategy. *Harvard Business Review*, **85**, 85-96.

[6] Bhaskar, V. and Lallement, P. (2010) Modelling a Supply Chain Using a Network of Queues. *Applied Mathematical Modelling*, **34**, 2074-2088. https://doi.org/10.1016/j.apm.2009.10.019

[7] Al-Amin Molla, Md. (2017) Case Study for Shuruchi Restaurant Queueing Model. *IOSR Journal of Business and Management*, **19**, 93-98. https://doi.org/10.9790/487X-1902039398

[8] Woensel, T.V. and Vandaele, N. (2007) Modelling Traffic Flow with Queuing Models: A Review. *Asia-Pacific Journal of Operational Research*, **24**, 435-461. https://doi.org/10.1142/S0217595907001383

[9] Hamdi, M.M., Mahdi H.F., Abood, M.S., Mohammed, R.Q., Abbas, A.D. and Mohammed, A.H. (2020) A Review on Queue Management Algorithms of Large Networks. *2nd International Scientific Conference of Engineering Sciences* (*ISCES* 2020). *IOP Conference Series*: *Materials Science and Engineering*, **1076**, Article ID: 012034. https://doi.org/10.1088/1757-899X/1076/1/012034

[10] Iversen, V.B. (2015) Teletraffic Engineering and Network Planning. DTU Fotonik, Kongens Lyngby.

[11] Osahenvemwen, O.A. and Odiase, O.F. (2016) Effective Utilization of Mobile Call Centre Using Queuing Models. *International Journal of Engineering and Technology*, **8**, 107-111. https://doi.org/10.7763/IJET.2016.V6.867

[12] Bose, S.N. (2015) An Analysis of Telecommunication Queuing System and Making More Efficient with Empirical Distribution of Service Time and Inter-Arrival Time (F-I-F-O Service). *International Journal of Science Technology and Engineering*, **2**, 137-142.

[13] Forrester, J.W. (2009) Some Basic Concepts in System Dynamics, Sloan School of Management. Massachusetts Institute of Technology, Cambridge, MA.

[14] Yusoff, M.I.M. (2020) The Use of System Dynamics in Building a Covid-19 Confirmed Case Model. *Computational and Mathematical methods in Medicine*, **2020**, Article ID: 9328414. https://doi.org/10.1155/2020/9328414

[15] Yusoff, M.I.M. (2018) The Behaviour of Procurement Process as Described by Using System Dynamics Methodology. *Advances in Operation Research*, **2018**, Article ID: 6721912. https://doi.org/10.1155/2018/6721912

Appendix A

A1: A Numerical example of how "Waiters" Model 1 behaves: Number of ports to be procured equals to (1 + percentage) multiplied by the number of waiters registered on the 30th of each month (*i.e.*, percentage can be assigned with a value between 0 and 100); refer to Equation (2) in **Figure A1**. They are converted into available ports on the 15th of the following month. In the meantime, new waiters will be registered (adding to the existing waiters) between 1st and 15th of the following month due to available ports being equal to zero (0). Waiters on the 30th of the previous month will be converted (into active customers) first. If there are available ports, waiters registered between 1st and 15th of the following month and new applications (after 15th of the following month) will be converted into active customers (*i.e.,* the said process continues until available ports equal to zero and new applications are converted into waiters). If available ports are equal to zero, new applications (after 15th of the following month) will be converted into waiters and only limited number of waiters (depending on the value of percentage) between 1st and 15th of the following month will be converted into active customers (refer to equations (2) and (3) on the y-axis in **Figure A1**).

$$\sum_{t=1}^{30} w_t \tag{1}$$

w_t = number of waiters at time t, $t = 1, 2, 3, \cdots$

$$(1+a)\left(\sum_{t=1}^{30} w_t\right) = p = \text{number of procured ports,} \tag{2}$$

$$a = 0.0(0\%), 0.1(10\%), 0.2(20\%), 0.3(30\%), \cdots$$

p = number of active customers = number of available ports

$$\left(\sum_{t=31}^{45} w_t\right) - a\left(\sum_{t=1}^{30} w_t\right) = \text{number of (remaining) waiters} \tag{3}$$

is derived from the following equations:

$$\left(\sum_{t=1}^{45} w_t\right) - (1+a)\left(\sum_{t=1}^{30} w_t\right) = \left(\sum_{t=1}^{30} w_t + \sum_{t=31}^{45} w_t\right) - (1+a)\left(\sum_{t=1}^{30} w_t\right)$$

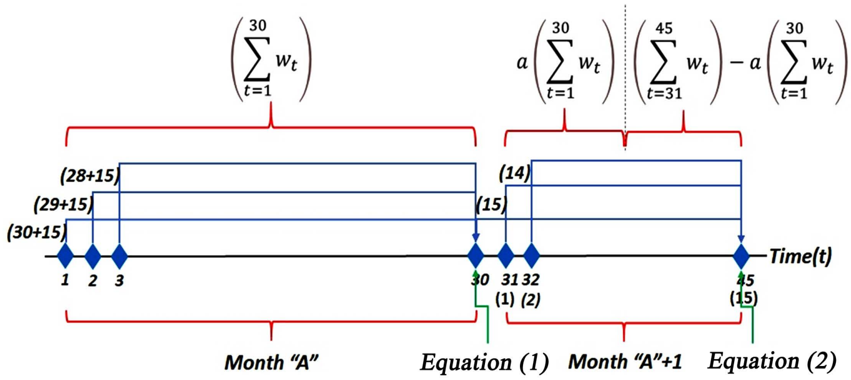
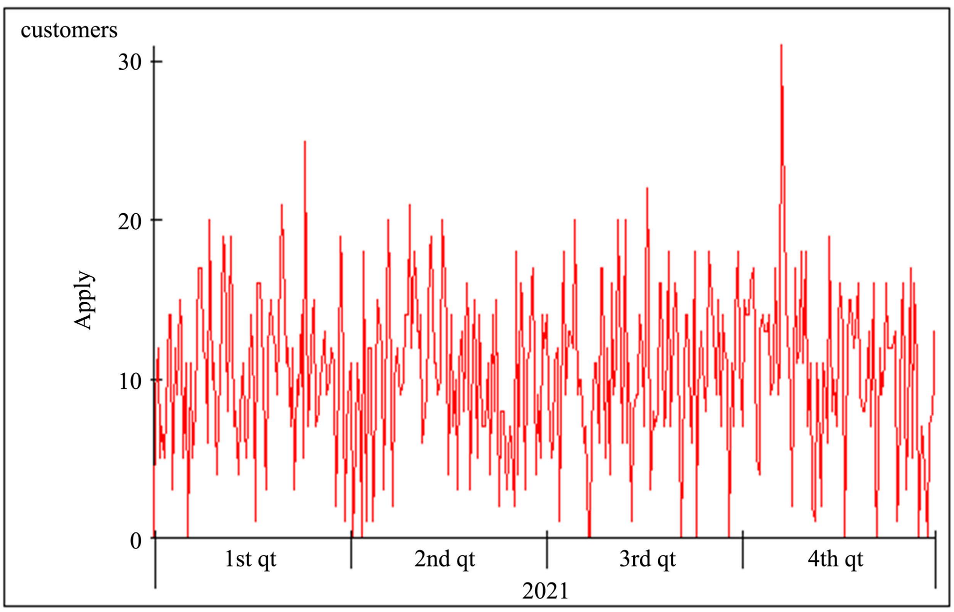
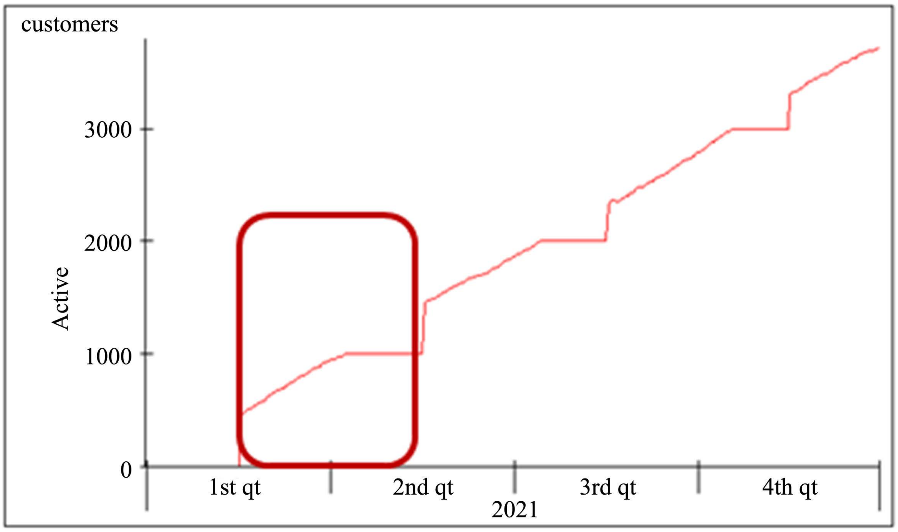


Figure A1. "*Waiters*" *Model 1* behaviour in "visual" presentation.

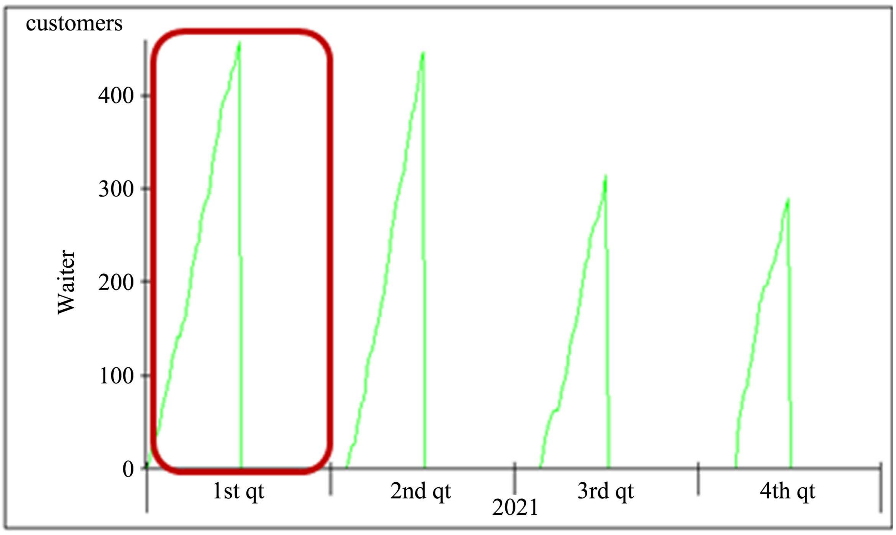
A2: "*Waiters*" *Model 1* where "Auxiliary_11" and "Auxiliary_16" are fixed at "Fixed (×1000)", 1, respectively. Figure A2(a) shows normal (10;5) behaviour for "Apply". Note that there are days "Apply" equals to zero, 0. Figure A2(b), especially highlighted by rectangular-coloured red, shows mixture of "step-shaped" and "linear-shaped" shaped behaviours. The "flat-shaped" behaviour occurs when "Available ports" equal to zero (0). The said behaviour was repeated until the end of simulation time. Note that on average, **98.94%** (with standard Deviation equals to **0.19**) of those "Apply" are converted into "Active". Figure A2(c), especially highlighted by rectangular-coloured red, shows "left-triangle-shaped" behaviour (*i.e.*, when "Available Ports" are not equal to zero, 0, and serving the customers). The said behaviour was repeated until the end of simulation time. "Waiter" is zero in the same simulation period as "Procured Ports" are converted into "Available Ports"; refer to Figure A2(e) and Figure A2(g). Figure A2(d) shows "step-shaped" behaviour for "Churn" (impacting on Figure A2(e) and Figure A2(f)). Figure A2(e), especially highlighted by rectangular-coloured red, shows "right-triangle-shaped" behaviour. The said behaviour was repeated until the end of simulation time. "Available Ports" are not available until "Procured Ports" conversion; refer to Figure A2(g). Figure A2(f) shows that "Active Ports" behaves in similar fashion as "Active"; refer to Figure A2(b). Figure A2(g), especially highlighted by a rectangular-coloured red, shows "column-shaped" behaviour. The decreased behaviour occurs when "Procured Ports" are converted into "Available Ports". The said behaviour repeated until the end of simulation time. Note that due to behaviour of "Apply" in Figure A2(a), "Procured Ports" peaked "consistently" at 1000. Figure A3 shows the combination (as well as their dependencies) of Figure A2(c), Figure A2(e), and Figure A2(g).



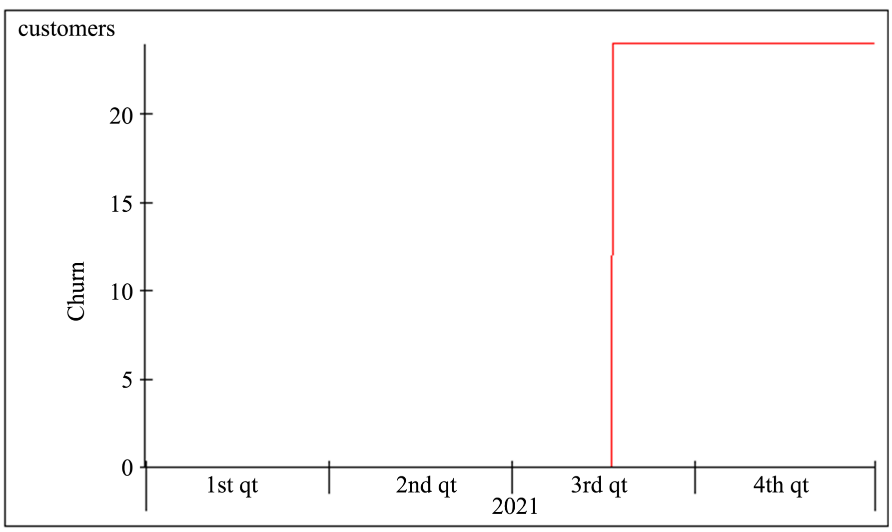
(a)


customers
3000
2000
1000
0
Active
1st qt
2nd qt
3rd qt
4th qt
2021

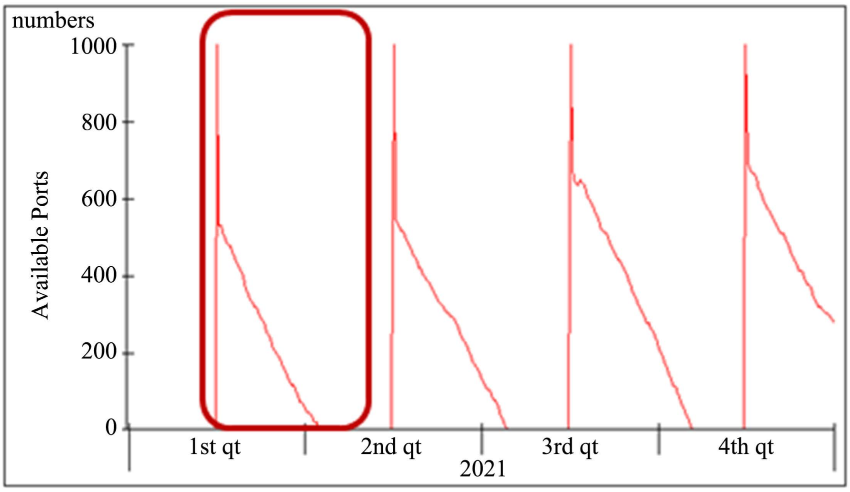
(b)


customers
400
300
200
100
0
Waiter
1st qt
2nd qt
3rd qt
4th qt
2021

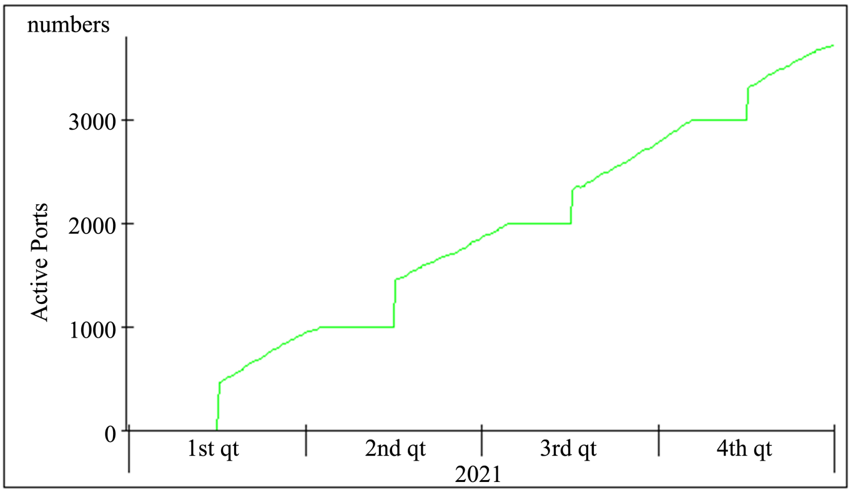
(c)


customers
20
15
10
5
0
Churn
1st qt
2nd qt
3rd qt
4th qt
2021

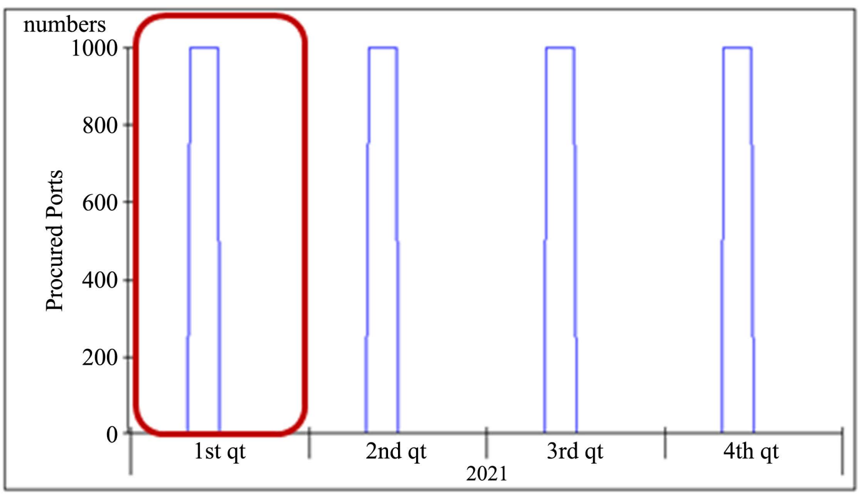
(d)



(e)



(f)



(g)

Figure A2. (a) "Apply", (b) "Active", (c) "Waiter", (d) "Churn", (e) "Available Ports", (f) "Active Ports", and (g) "Procured Ports" versus simulation time for "*Waiters*" *Model 1* ("Fixed (×1000)", 1).

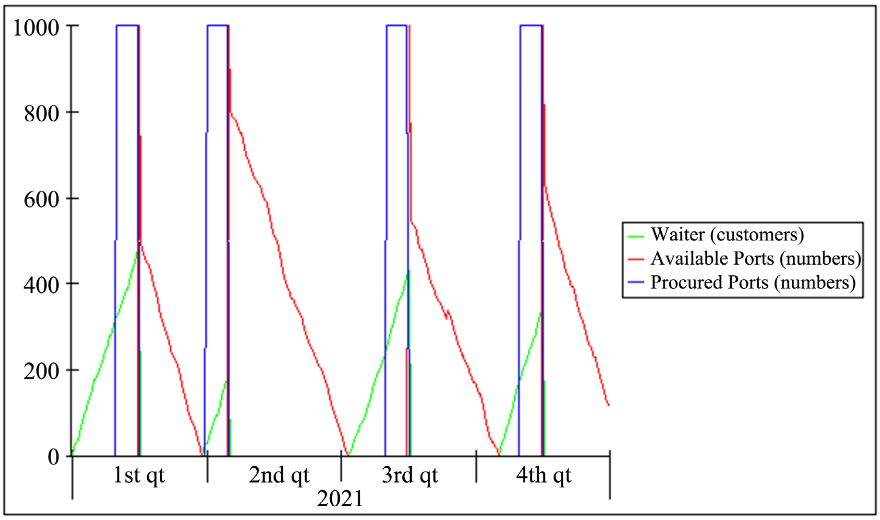


Figure A3. "Waiter", "Available Ports", and "Procured Ports" graphs are combined for "*Waiters*" *Model 1* ("Fixed (×1000)", 1).