A SYSTEM DYNAMICS MODEL TO DETERMINE THE VALUE OF INVENTORY HOLDING COST

BABATUNDE OMONIYI ODEDAIRO*1, EMILOLA HELEN ALABA[1], INYENEOBONG EDEM[1]

[1]*Department of Industrial and Production Engineering, Faculty of Technology, University of Ibadan, Oyo State, Nigeria*

Abstract: Traditionally, Inventory Holding Cost (IHC) is assumed to be a combination of several costs and determined by the summation of these cost components. Several authors have suggested that the value of IHC ranges between 12-50% of the procurement cost of an item. However, due to the absence of a generally acceptable methodology, many practitioners still determine this percentage based on estimates, benchmarks and intuition. Giving considerations to this reality, a mathematical model to determine the value of IHC using systems dynamics approach was developed. IHC was viewed holistically to identify relevant quantities, their interactions (static or dynamics), behaviour and consequences. A Causal Loop Diagram (CLD) was developed to establish the relationship among these quantities. Thereafter, CLD was transformed into a Flow Diagram (FD). FD was used to formulate a set of systems dynamics equations to obtain IHC. The interaction among fraction of goods ordered per month (FOM), fraction sold per month (FSM) and fraction damaged per month (FDM) was simulated to obtain percentage values of IHC. The value of IHC obtained from the model and simulation analysis ranges between 22.58-25.39% of the item held in stock. Based on these results, it is concluded that the developed model can be used for simulation and system analysis of the holding cost component of an inventory system under different contextual settings.

Keywords: inventory holding cost, system dynamics, causal loop diagram, simulation

1. INTRODUCTION

Inventory Holding Cost (IHC) is a variable cost and a required input in the computation of total inventory cost. To determine IHC, Onanuga [1] commented that relevant cost components are ignored by practitioners and inventory managers. Miller [2] and Azzi et al. [3] opined that the decision to ignore these components could be as a result of rigors and complexities associated with mathematical computations.

Foster [4] suggested twenty-seven (27) cost components that should be summed to obtain total inventory holding cost, these components can be categorised into five (capital, storage space, handling equipment, inventory risk and inventory service). Azzi et al. [3] argued that IHC can be derived from the sum of storage and opportunity costs expressed as a percentage of the mean inventory investment. Opportunity cost are cost incurred when capital is tied up in inventory rather than being invested in other business activities. Lambert et al. [5] reduced the categories suggested by Foster [4] into four, they asserted that IHC should include costs that vary with the quantity of inventory stored. Harding [6] classified these components into fixed and variable cost factors while Durlinger [7] opined that the components should be determined based on individual organisation.

* Corresponding author, email: bo.odedairo@ui.edu.ng

To obtain the value of IHC, Teunter et al. [8] commented that practitioners still use estimates, benchmarks and intuition because a generally accepted methodology has not been fully established. This reality had been corroborated in literature with a conclusion that while several studies have been carried out, it is still difficult for managers to estimate the value of IHC [4]. Traditionally, the value of IHC is computed as a fraction of the item held in inventory. For industrial applications, Naddor [9] opined that it should vary between 5-25% per year. However, depending on the industry type, the value ranges between 12-35% [5]. Pyke and Cohen [10] estimated the value at 20-50%. In their pull inventory model, Clendenen and Rinks [11] assumed holding cost to be 30% of the product value. Miller [2] pegged IHC at 25% of the unit price of an item per annum. From literature, a common number for inventory holding cost is 25% per annum of the purchasing price of an item [7]. Rajhans et al [12] argued that an accurate estimate can only be derived considering relevant cost components which may vary from industry to industry at different time interval.

Arising from the myriads of different cost components and values of IHC suggested in literature, the interactions (static or dynamic), behaviors and consequences among these components is expected to create a multi-dimensional problem. Therefore, a holistic approach to ascertain the value of IHC problem will assist to reveal hidden feedback loops and counterintuitive relationship among the components. Systems dynamics (SD) modelling is designed precisely for problems possessing these characteristics [13]. SD focuses on the structure and behaviour of systems with interacting feedback loops [14]. SD can be used to develop and test mathematical models as well as simulation of complex dynamic systems [15]. SD has been applied in different fields including supply chain management [16], cost of quality system [17], strategic cost management [18] and inventory management [19].

Based on the reality that IHC can affect profitability and performance of an inventory system [20], Holsenback and McGill [21] opined that it should be diligently measured. Therefore, in this study, a mathematical model to determine the value of IHC using systems dynamics is formulated.

1.1. Review of inventory holding cost

Inventory constitute a wide range of materials with the capability to be packaged, stored, transferred, used for production, etc. Sometimes, it is often referred to as collection of idle resources (tangible and intangible) with monetary values. Some of the reasons to hold inventory cited includes fluctuations in demand, price protection, lead time variability, supplier unreliability and quantity discounts [2, 22]. Furthermore, the need to hold inventory requires that some ancillary supports (i.e. activities) must be provided. These include but not limited to the following: (i) acquisition of warehouse and equipment for inventory handling/storage (ii) inspection and counting of inventory (iii) payment of tax (iv) utilisation of energy in form of light, heat and power. Usually, certain costs will be incurred when these activities are executed. Foster [4] and other authors suggested some cost components, these components are reviewed in Table 1.

Table 1. Components of Inventory Holding Cost suggested by different authors.

Foster [4]	Other Authors
1) Taxes on land and building 2) Taxes on inventory	(i) Taxes on land, building, equipment and inventory were considered altogether as tax [2, 3, 23, 24, 25]. (ii)Lambert et al. [5] argued that tax on building is irrelevant because the payment will continue whether or not inventory is kept.
3) Insurance on inventory 4) Insurance on building. 5) Insurance and taxes on equipment	(i) Insurance on land, building, equipment and inventory were considered altogether as tax [2, 3, 23, 24, 25]. (ii) Lambert et al. [5] considered only “insurance on inventory” as relevant.
6) Depreciation on building (for owned warehouse). 7) Depreciation on warehouse installations. 8) Depreciation on equipment	(i) Rajhans et al. [12] considered them relevant. (ii) This cost are not relevant because they are not “out of pocket cost” [23, 24]. (iii) Lambert et al. [5] stated that they are fixed and should not be considered. Other authors did not give reasons for ignoring these costs.
9) Maintenance and repairs on building. 10) Maintenance and repair of equipment	(i) These components were considered relevant [3, 12, 25]. (ii) Other authors did not give reasons for ignoring these costs
12) Utility cost (heat, light and water) 13) Fuel for equipment	(i) This cost were named as “warehouse operating cost” [23, 24] (ii) Miller [2] and Azzi et al. [3] referred to them as “utility cost” (iii) Other authors did not give reasons for ignoring these costs
13) Janitor, watchman and maintenance salaries 14) Labour costs of handling and maintaining stocks 15) Clerical costs of keeping records	(i) This cost were considered as “Manpower cost” [2] (ii) Harding [6] referred to these costs as “Personnel cost” (iii) Ziegler [25] considered these costs as material handling and physical inventory cost. (iv) Azzi et al. [3] considered these components as “direct and Indirect labour cost”. (v) Other authors did not give reasons for ignoring these costs

Foster [4]	Other Authors
16) Rent (if paid)	(i) This is considered relevant by all the authors and are referred to as “Storage space cost”, “Storage cost” or “Warehouse cost”
17) Obsolescence of inventory 18) Physical deterioration of inventory 19) Pilferage 20) Losses resulting from inventory price declines	(i) This cost are considered relevant by all the authors. Most authors group them together as “Risk cost”
21) Employer contribution to social security for all space, handling and inventory service personnel 22) Unemployment compensation insurance for all space, handling and service personnel 23) Employer contributions to pension plans, group life, health and accident insurance programs for all space, handling and inventory service personnel. 24) A proportionate share of general administrative overhead, including all taxes, social security, pension and employer contributions to insurance programs for administrative personnel	(i) Not considered relevant by any of the authors whose literature were reviewed
25) Interest on money invested in inventory	(i) Generally referred to as “Capital cost” or “Opportunity cost” by several authors
26) Interest on money invested in inventory handling and control equipment 27) Interest on money invested in land and building to store inventory (if owned)	(i) Lambert et al. [5] referred to these components as “Capital cost of assets”

From Table 1, it is obvious that the components of IHC will largely depend on the type of industry, product offerings, scale of operations, etc. In terms of scale, small and medium industries which often utilize manual warehousing system are likely to incur extra costs from product damage, pilferage, and inspection /counting. Also, these components must be explicitly considered; therefore, some of the components presented in Table 1 were further categorized into fixed cost (F_c), variable cost (V_c) and risk cost (R_c) as presented in Table 2. While fixed and variable costs are relevant to all industries, the latter is dependent on the inventory level while the former is incurred by the reason of keeping inventory. On risk cost, the type of product will determine whether to consider it or not. For example, in machinery and equipment sector, high risk of obsolescence is prevalent due to advances in technology; whereas in the textile industries, obsolescence cost is minimized as products can be remanufactured.

Table 2. Categorization of some IHC components into fixed, variable and risk costs.

Cost components	Description	Category
Capital cost of inventory	Cost of the capital tied up or the opportunity cost of investment in inventory.	F_c
Capital cost of assets	Opportunity cost of investment in warehouse and storage equipment (if owned)	F_c
Warehouse cost	Cost of acquiring (renting) a warehouse to store inventory	F_c
Energy cost/ Utility cost	Cost incurred on utilities required to operate the warehouse and equipment such as electricity, gas, oxygen, fuel, etc	F_c
Maintenance Cost	Annual maintenance cost and the monthly breakdown maintenance cost on building and storage equipment	F_c
Labour Cost	Salary of all workers involved in inventory management	F_c
Warehouse depreciation cost	Depreciation on building and warehouse installations (if owned)	F_c
Handling equipment depreciation cost	Depreciation on storage/handling equipment such as shelves, pallets, racks, etc. (if owned)	F_c
Insurance on Warehouse	Insurance paid for storage space.	F_c
Inventory Insurance	Insurance paid for inventory	V_c
Insurance on Storage equipment	Insurance paid for Storage/handling equipment	F_c
Taxes on Inventory	Taxes paid on inventory	V_c
Taxes on Warehouse	Taxes paid on warehouse land and building	F_c
Taxes on Storage equipment	Taxes paid on storage equipment	F_c
Obsolescence cost	This describes the cost attached to the risk of inventory never being used.	R_c
Product damage/depreciation and deterioration cost	Cost of product damage due to overcrowding of the warehouse, depreciation due to decline in price of inventory and deterioration for perishable goods whose life cycle is short	R_c
Cost of pilferage/theft	Cost incurred when items stored are stolen.	R_c
Cost of Repacking and Relabelling /Remanufacturing	Cost incurred when items are repackaged or remanufactured when damaged	R_c
Inventory inspection and counting cost	Cost of inspecting and counting during the year especially for inventory which are easily damaged or have short life cycle	F_c
Relocation cost	Cost of transporting inventory from one warehouse to another in order to prevent obsolescence	R_c
Other business specific cost	This refers to other cost components that are peculiar to individual industries.	Depends on the definition of the cost

2. RESEARCH METHOD

2.1. Description of inventory holding cost (IHC) problem

The need to hold inventory could arise when finished goods are ordered (or produced) and the quantity utilised (or sold) is lower ordered quantity. Arising from the decision to hold, activities such as warehousing, maintenance, cleaning service, inspection, disposal, repackaging and personnel management must be implemented. These activities will contribute IHC and if the stocks are not properly monitored, the firm risk loss due to damage, spoilage and obsolescence. Hence, the need to consider these components and opportunities available to obtain an acceptable value of inventory holding cost. In Figure 1, the procedure to investigate the relationships between these components and formulate a mathematical model using system dynamics is presented.

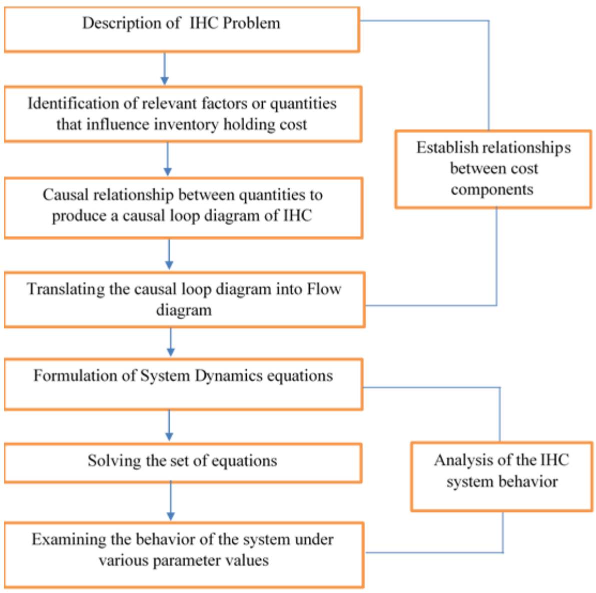


Fig. 1. Procedure for formulation of mathematical model for inventory holding cost.

2.2. Identification of quantities in inventory holding system

In Table 3, the quantities in inventory holding system used in this work, notations and their dimensions are listed.

Table 3. Quantities and dimensions.

Quantity	Notation	Dimension
Inventory level	INV	Q (quantity)
Desired Inventory level	DINV	
Discrepancy	DISC	
Replenishment rate	OR	$\frac{Q}{t}$ t = time
Consumption rate	SR	
Damage rate	DR	
Fraction ordered per month	FOM	$\frac{1}{t}$
Fraction sold per month	FSM	
Fraction damaged per month	FDM	
Unit price of inventory	P	$\frac{₦ \text{ (Currency)}}{Q}$
Tax rate per unit inventory	T_r	
Insurance per unit inventory	I_r	
Average life of warehouse in months	U_w	t
Average life of equipment in months	U_e	
Interest rate	R	Dimensionless
Investment	I	₦
Capital cost	C	
Insurance on inventory	I_i	
Tax on inventory	T_i	
Warehouse cost	W_c	
Labour cost	L_c	

Quantity	Notation	Dimension
Energy cost	E_c	
Cost of equipment	C_e	
Cost of warehouse	C_w	
Depreciation cost of warehouse	D_w	
Depreciation cost of warehouse equipment	D_e	₦
Insurance on warehouse and equipment	I_w	
Maintenance cost	M_c	
Damage cost	D_c	
Inventory Holding cost	IHC	

2.3. Formulation of mathematical model

The modeling started with the development of a causal loop diagram (CLD) to depict the dynamic behaviour in the inventory holding system. In this research, CLD is limited to internal factors that influence the inventory holding system. In system dynamics, CLD simplify the illustration of a model and serves as a preliminary sketch. In a CLD, the direction of influence is shown by the arrow, while plus (+) or minus (-) signs indicate the type of relationship between any pair of quantities. The relationship between the quantities is positive if a change in one quantity produces a change in the same direction for the second quantity while the relationship is negative if a change in one quantity produces a change in the opposite direction for the second quantity. Thereafter, CLD is transformed into a flow diagram (FD) to depict rate, state and flow in the inventory holding system. In system dynamics, rate represents an action which brings about a change of the state of the system. State describes the accumulation of resources or the present condition of the system as a result of the rate. Flow represents the direction of flow of rate in or out of the state.

2.4. Causal loop diagram for IHC

The CLD in Figure 2 describes a causal relationship between the 30 quantities identified in Table 3.

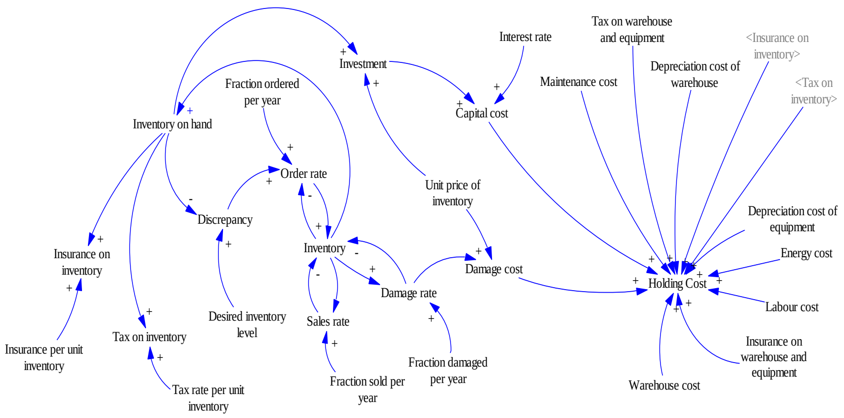


Fig. 2. Causal Loop Diagram for Inventory Holding System.

The CLD revealed that the more the order rate, the more the inventory and the more the sales rate and damage rate. Increase in fraction ordered per month, fraction sold per month and fraction damaged per month resulted in an increase in order rate, sales rate and damage rate, respectively. Furthermore, increase in inventory and unit price of inventory leads to increases in investment. Increase in interest rate and investment caused an increase in capital cost and increase to holding cost.

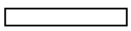
CLD further revealed that holding cost is dependent on the warehouse cost, labour cost, energy cost, damage cost, tax on warehouse and equipment, insurance on warehouse and equipment, depreciation on warehouse, depreciation on equipment, tax on inventory, insurance on inventory, and maintenance cost

2.5. Flow diagram

In system dynamics, rate represents an action which brings about a change in the state of the system, state describes the accumulation of resources or the present condition of the system as a result of the rate, and flow represents the direction in or out of the state. In Table 4, the rates, state, inputs, auxiliary, output and symbols required to construct a FD are described. The CLD highlighted in Figure 2 was transformed into flow diagram presented in Figure 3.

Table 4. Components of IHC Flow diagram and their Notations.

S/N	Quantity Type	Quantity	Notation
1.	Rates	Replenishment rate	OR
		Consumption rate	SR
		Damage rate	DR
2.	State	Inventory level	INV
3.	Inputs	Fraction ordered per month	FOM
		Fraction sold per month	FSM
		Fraction damaged per month	FDM
		Desired Inventory level	DINV
		Interest rate	R
		Unit price of inventory	P
		Insurance per unit inventory	I_r
		Tax rate per unit inventory	T_r
		Tax on warehouse building and equipment	T_b
		Insurance on warehouse building and equipment	I_b
		Warehouse cost	W_c
		Labour cost	L_c
		Average life of equipment in months	U_e
		Cost of equipment	C_e
		Average life of warehouse in months	U_w
		Cost of warehouse	C_w
		Maintenance cost	M_c
		Energy Cost	E_c
4.	Auxiliaries	Discrepancy	DISC
		Investment	I
		Capital cost	C
		Insurance on inventory	I_i
		Tax on inventory	T_i
		Depreciation cost of warehouse	D_w
		Depreciation cost of warehouse equipment	D_e
		Insurance on warehouse and equipment	I_w
		Insurance on equipment	I_e
		Damage cost	D_c
5.	Output	Total Inventory Holding cost	TIHC

Symbols used in the construction of flow diagram	
	Source
	Rate
	Flow
	Information
	Stare or Stock

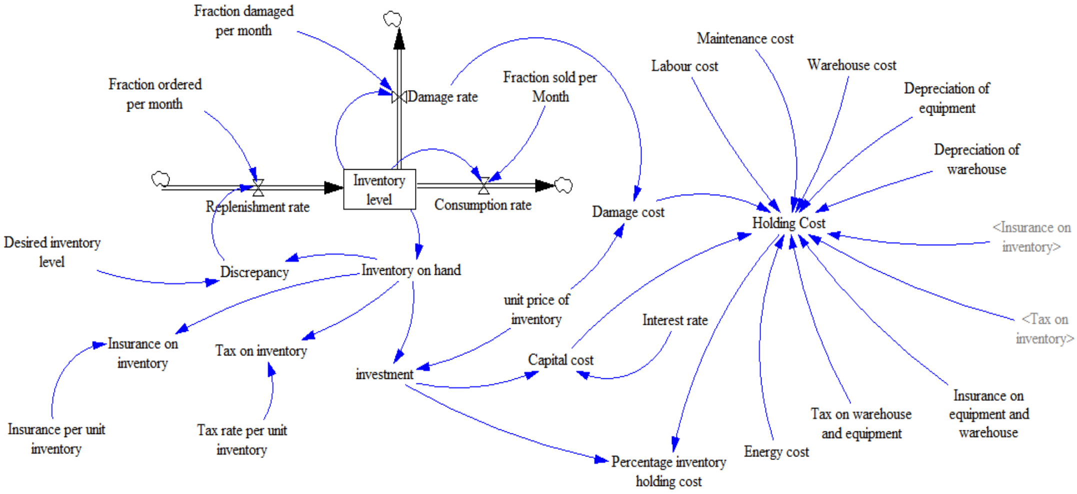


Fig. 3. Flow Diagram for IHC.

2.6. Formulation of system dynamics equations for inventory holding cost

2.6.1. Model assumptions

The following assumptions guided the development of the model:
1. Inventory items are replenished instantaneously;
2. Time period is monthly.

2.6.2. Quantity type equations

2.6.2.1. Rate equations

The rate of change (RC) of the inventory level is expressed as:

$$\mathrm{RC} = inflow - outflow = d\,INV\,/\,dt = (\mathrm{OR} - \mathrm{SR}) - \mathrm{DR} \tag{1}$$

Considering the principle of dimensional consistency and dynamic equation formulation procedure, the equations for the order rate, sales rate and damage rate were developed as shown in equations (2), (3) and (4).

$$\mathrm{OR} = FOM*DISC \tag{2}$$

$$\mathrm{SR} = FSM*INV \tag{3}$$

$$\mathrm{DR} = FDM*INV \tag{4}$$

Substituting equations (2), (3) and (4) into (1) yields equation (5).

$$\mathrm{RC} = (FOM*DISC) - (FSM*INV) - (FDM*INV) \tag{5}$$

Equation (5) can be rearranged as described in equation (6):

$$\mathrm{RC} = (FOM*DISC) - (FSM + FDM)*INV \tag{6}$$

2.6.2.2. Auxiliary equations

The auxiliary equations are developed from equations (7) to (15):

Discrepancy:

$$DISC = DINV - INV \tag{7}$$

Investment:

$$\mathrm{I} = INV*P \tag{8}$$

Capital cost:

$$C = I * R = INV * P * R \quad (9)$$

Insurance on inventory:

$$I_i = I_r * INV \quad (10)$$

Tax on inventory:

$$T_i = T_r * INV \quad (11)$$

Depreciation cost of warehouse:

$$D_w = C_w / U_w \quad (12)$$

Depreciation cost of warehouse equipment:

$$D_e = C_e / U_e \quad (13)$$

Damage cost:

$$D_c = DR * P \quad (14)$$

Equation (14) can be rewritten when DR from equation (4) is substituted to obtain equation (15):

$$D_c = FDM * INV * P \quad (15)$$

2.7. Output equation

From the flow diagram, the output equation (THIC) can be derived by considering the auxiliary equations and input parameters.

$$THIC = C + W_c + M_c + L_c + E_c + D_c + D_e + D_w + T_i + I_i + T_b + I_b \quad (16)$$

Substitute equations (9), (10), (11), (12), (13) and (15) into (16) to obtain (17).

$$THIC = (INV * P * R) + W_c + M_c + L_c + E_c + (FDM * INV * P) + (C_e/U_e) + (C_w/U_w) + (T_r * INV) + (I_r * INV) + T_b + I_b \quad (17)$$

2.8. Determination of state variable (*INV*)

From equation (17), INV is a decision variable which can be obtained using Euler solution method.

$$S(t_{i+1}) = S(t_i) + \Delta RC(t_i) \quad (18)$$

From equation (18), the state variable (S) can be replaced by *INV*; while t_i is the index dimension of time period where $i = 1,\ldots,12$.

Therefore,

$$INV(t_{i+1}) = INV(t_i) + \Delta RC(t_i) \quad (19)$$

From equation (6), RC can be rewritten as depicted in equation (20):

$$RC = FOM * (DINV - INV) - (FSM + FDM) * INV \quad (20)$$

From equation (20), RC can be expressed as function time (t_i):

$$RC(t_i) = FOM * (DINV - INV(t_i)) - (FSM + FDM) * INV(t_i) \quad (21)$$

The state variable, *INV* (in equation 19) can be rewritten as presented in equation (22).

$$INV\,(t_{i+1}) = INV\,(t_i) + FOM * (DINV\text{-}INV\,(t_i)) - (FSM+FDM) * INV\,(t_i) \quad (22)$$

Clearly, equation (22) can be used to simulate the level of inventory at period t +1. Also, decisions in period t is expected to have consequences that will be carried into period t +1.

2.9. Value of inventory holding cost

Usually, the value of IHC (denoted as ʋ) is computed as a percentage (fraction) of item held in stock as depicted in equation (23).

$$\upsilon = THIC / I * 100 \quad (23)$$

3. RESULTS AND DISCUSSION

3.1. Model application and simulation

To verify the applicability of the model, data was collected from a distribution unit of a selected bottling company located in south west of Nigeria for a period of 12 months (January- December 2019).

The values (in units) of the initial inventory level, desired inventory level, annual quantity of goods ordered, average quantity of goods ordered monthly, annual quantity of goods sold, average quantity of goods sold monthly, annual quantity of goods damaged and average quantity of goods damaged monthly were 8258, 50000, 297196, 24766, 280103, 23342, 21350 and 1779, respectively. Also, the unit price of inventory and tax rate were ₦ 1100 and 0.0484, respectively.

3.1.1. Model application

The values of the cost components and total inventory holding cost for the company were computed using equations (9) - (17) as summarised in Table 5.

Table 5. Computation of inventory holding cost.

Cost component	Amount(₦)
Capital cost	1,271,732
Warehouse cost	105,000
Maintenance cost	0
Labour cost	125,000
Energy cost	22,583.33
Damage cost	726,704
Consumables/Utility cost	5,200
Depreciation on equipment	49,826.42
Depreciation on warehouse	0
Tax on inventory	399.69
Insurance on inventory	0
Tax on warehouse and equipment	0
Insurance on warehouse and equipment	0
Total Inventory Holding Cost (TIHC)	2,306,445.44

From Table 5, capital cost constituted the largest percentage (55.13%) of the holding cost, this amount reaffirmed some observation from literature [7, 26]. Using equation (23), the value of IHC (ʋ) was calculated as 25.39% (i.e. 2306445.44 /1100*8258).

3.2. Model simulation

With FOM =1, FSM =0.9 and FDM = 0.08 derived from the inventory records presented in section 3.1, ʋ was simulated for 12 months using equation (22) as shown in Table 6.

Table 6. Simulation results for ʋ.

t	INV	I	C	T_i	D_c	TIHC	ʋ
0	8258	9083800	1271732	399.6872	726704	2306445	25.39
1	41907.16	46097876	6453703	2028.307	3687830	10451171	22.67
2	8930.983	9824082	1375371	432.2596	785926.5	2469340	25.14
3	41247.64	45372400	6352136	1996.386	3629792	10291534	22.68
4	9577.316	10535048	1474907	463.5421	842803.8	2625784	24.92
5	40614.23	44675653	6254591	1965.729	3574052	10138219	22.69
6	10198.05	11217860	1570500	493.5858	897428.8	2776033	24.75
7	40005.91	44006497	6160910	1936.286	3520520	9990975	22.70
8	10794.21	11873633	1662309	522.4398	949890.6	2920331	24.60
9	39421.67	43363840	6070938	1908.009	3469107	9849563	22.71
10	11366.76	12503437	1750481	550.1512	1000275	3058916	24.46
11	38860.57	42746632	5984528	1880.852	3419731	9713750	22.72
12	11916.64	13108301	1835162	576.7652	1048664	3192013	24.35

3.3. System analysis

Using the developed model, the effect of changes in FSM (at 0.7, 0.5. 0.3 and 0.1) on THIC was determined. FSM is critical to the system because holding cost is applicable to items held in stock, hence the impact on item at hand is critical to better understand the system.

Clearly, TIHC increases with decrease in the value of FSM as presented in Tables (7), (8), (9) and (10).

Table 7. Computation for ʋ at FSM= 0.7.

t	INV	I	C	T_i	Dc	TIHC	ʋ
0	8258.00	9083800.00	1271732.00	399.69	726704.00	2306445.44	25.39
1	43558.76	47914636.00	6708049.04	2108.24	3833170.88	10850937.91	22.65
2	16024.17	17626583.92	2467721.75	775.57	1410126.71	4186233.78	23.75
3	37501.15	41251264.54	5775177.04	1815.06	3300101.16	9384703.00	22.75
4	20749.10	22824013.66	3195361.91	1004.26	1825921.09	5329897.01	23.35
5	33815.70	37197269.35	5207617.71	1636.68	2975781.55	8492645.69	22.83
6	23623.75	25986129.91	3638058.19	1143.39	2078890.39	6025701.72	23.19
7	31573.47	34730818.67	4862314.61	1528.16	2778465.49	7949918.01	22.89
8	25372.69	27909961.44	3907394.60	1228.04	2232796.91	6449029.30	23.11
9	30209.30	33230230.08	4652232.21	1462.13	2658418.41	7619722.50	22.93
10	26436.75	29080420.54	4071258.88	1279.54	2326433.64	6706581.81	23.06
11	29379.34	32317271.98	4524418.08	1421.96	2585381.76	7418831.55	22.96
12	27084.12	29792527.86	4170953.90	1310.87	2383402.23	6863276.75	23.04
Total						89583924.47	

Table 8. Computation for ʋ at FSM = 0.5.

t	INV	I	C	T_i	Dc	TIHC	ʋ
0	8258.00	9083800.00	1271732.00	399.69	726704.00	2306445.44	25.39
1	45210.36	49731396.00	6962395.44	2188.18	3978511.68	11250705.05	22.62
2	23777.99	26155790.32	3661810.64	1150.85	2092463.23	6063034.48	23.18
3	36208.77	39829641.61	5576149.83	1752.50	3186371.33	9071883.41	22.78
4	28998.92	31898807.86	4465833.10	1403.55	2551904.63	7326751.03	22.97
5	33180.63	36498691.44	5109816.80	1605.94	2919895.32	8338927.81	22.85
6	30755.24	33830758.97	4736306.26	1488.55	2706460.72	7751865.28	22.91
7	32161.96	35378159.80	4952942.37	1556.64	2830252.78	8092361.55	22.87
8	31346.06	34480667.32	4827293.42	1517.15	2758453.39	7894873.71	22.90
9	31819.28	35001212.96	4900169.81	1540.05	2800097.04	8009416.65	22.88
10	31544.81	34699296.49	4857901.51	1526.77	2775943.72	7942981.75	22.89
11	31704.01	34874408.04	4882417.13	1534.47	2789952.64	7981513.99	22.89
12	31611.68	34772843.34	4868198.07	1530.01	2781827.47	7959165.29	22.89
Total						99989925.42	

Table 9. Computation for υ at FSM= 0.3.

t	INV	I	C	T_i	Dc	TIHC	υ
0	8258.00	9083800.00	1271732.00	399.69	726704.00	2306445.44	25.39
1	46861.96	51548156.00	7216741.84	2268.12	4123852.48	11650472.19	22.60
2	32192.46	35411700.72	4957638.10	1558.11	2832936.06	8099742.02	22.87
3	37766.87	41543553.73	5816097.52	1827.92	3323484.30	9449019.49	22.74
4	35648.59	39213449.58	5489882.94	1725.39	3137075.97	8936294.05	22.79
5	36453.54	40098889.16	5613844.48	1764.35	3207911.13	9131129.72	22.77
6	36147.66	39762422.12	5566739.10	1749.55	3180993.77	9057092.16	22.78
7	36263.89	39890279.59	5584639.14	1755.17	3191222.37	9085226.43	22.78
8	36219.72	39841693.75	5577837.13	1753.03	3187335.50	9074535.41	22.78
9	36236.51	39860156.37	5580421.89	1753.85	3188812.51	9078598.00	22.78
10	36230.13	39853140.58	5579439.68	1753.54	3188251.25	9077054.22	22.78
11	36232.55	39855806.58	5579812.92	1753.66	3188464.53	9077640.85	22.78
12	36231.63	39854793.50	5579671.09	1753.61	3188383.48	9077417.93	22.78
Total						113100667.91	

Table 10. Computation for υ at FSM= 0.1.

t	INV	I	C	Ti	Dc	TIHC	υ
0	8258	9083800	1271732	399.69	726704	2306445.437	25.39
1	48513.56	53364916	7471088	2348.06	4269193	12050239.33	22.58
2	41267.56	45394315.12	6355204	1997.35	3631545	10296356.43	22.68
3	42571.84	46829023.28	6556063	2060.48	3746322	10612055.35	22.66
4	42337.07	46570775.81	6519909	2049.11	3725662	10555229.54	22.66
5	42379.33	46617260.35	6526416	2051.16	3729381	10565458.19	22.66
6	42371.72	46608893.14	6525245	2050.79	3728711	10563617.03	22.66
7	42373.09	46610399.24	6525456	2050.86	3728832	10563948.44	22.66
8	42372.84	46610128.14	6525418	2050.85	3728810	10563888.79	22.66
9	42372.89	46610176.94	6525425	2050.85	3728814	10563899.52	22.66
10	42372.88	46610168.15	6525424	2050.85	3728813	10563897.59	22.66
11	42372.88	46610169.73	6525424	2050.85	3728814	10563897.94	22.66
12	42372.88	46610169.45	6525424	2050.85	3728814	10563897.88	22.66
Total						130332831.5	

4. CONCLUSIONS

In this study, systems dynamics approach was applied to holistically consider the inventory holding cost system and relevant quantities that influence the system. A causal loop diagram was developed to capture the interrelationship among these quantities and a mathematical model for determination of inventory holding cost was formulated based on the established relationship. The percentage of inventory holding cost of the item price obtained from the model ranges between 22.58 – 25.39% which is in line with values recommended in literature.

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