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An Integrated Investment Scheduling Model for New Job Shops: A Phase-In Approach

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Abstract

The establishment and sustainability of the small-scale manufacturing sector is a great contributor to any nation's economic and technological development. A job shop is a typical small-scale manufacturing system that produces simple equipment and machine parts as well as technical services in developing nations. This type of manufacturing system requires versatile production machines for its activities. This requires enormous capital that most interested investors could not afford, and a majority of the commercial banks are not willing to provide financial assistance. This study develops a model using the theory of internal funding by employing the little initial capital in phasing- in the acquisition of the needed machinery, construction of factory space in modular forms, and adequate consideration for recurrent expenditure (i.e. working capital). The initial capital is periodically augmented from the ploughed-back earnings for the gradual acquisition of other machinery until a fully functional job shop emanates within the shortest possible time. Job shop general scheduling methods available in the literature could not be employed to solve the model developed in this study due to its peculiarities. Hence a special heuristic that employs suitable decision rules was formulated and solved using software developed for the purpose. The model developed in this study will be helpful to the investors in job shops, especially in developing nations, to overcome the problem of financing the venture.

1. Introduction

Mostly in developing nations, job shop is a small-scale manufacturing industries associated with low volume and a wide variety of products. This requires versatile and skilled manpower with varieties of machinery and specialised facilities utilised for multitasking production (Mahmod, 2014). In this situation, investment in machinery and equipment (M&E) becomes substantial and mainly above the financial capacity of interested investors, especially in developing countries. An investment in M&E is considered a significant source of growth for small-scale industries and a determinant for their future success and survival (Abdi, 2008; Menshikov et al., 2015). Financing this kind of investment is done through a loan from microfinancing institutions. However, job shops do experience difficulties accessing initial and expansion capital funds from these institutions due to the nature of their products, which are usually undefined, and the cash flow is not readily predictable (Aderoba, 1997; Cusmano, 2015; Prihastiwi et al., 2021; Taiwo & Falohun, 2016). Based on this financial constraint, the capital owned by the owner becomes the only source of financing for the project, which often than not, insufficient to procure all the necessary M&E, construct factory building and carter for the working capital (Evbuomwan et al., 2012; Prihastiwi et al., 2021). Hence, interested investors in job shops are left with an option to start with little available funds to acquire a few from the required M&E, construct a section of the factory space and provide for the working capital. Then the job shop gradually expands to a full capacity by ploughing back earnings from the investment.

Sequential acquisition of M&E through internal funding in a job shop is an investment decision that could be difficult (Vranakis & Chatzoglou, 2012). This is because such decisions are clouded by unpredictable demand patterns, inconsistent cost of production, product differentiation, dynamic technology, and rigid factory layouts (Aderoba, 1997; Sohn et al., 2007). Due to the non-availability of a simple scientific approach to guide the investors, sequential investment decisions on M&E are primarily based on investors' intuitions that are not always right and eventually result in the venture's failure (Oladimeji & Aladejebi, 2020).

This study aims to provide a simple mathematical model to schedule and optimise the acquisition of M&E using different decision rules. This is to assist a new investor in a job shop that could not afford to start the investment in M&E and factory building in one fell swoop but planned to start from small and gradually expand to the full capacity through the plough back earnings from the installed and used M&E. The study will also provide user-friendly software using Microsoft Excel VBA for the implementation of the model. The software will not only make the usage of the model easy to implement but makes it readily available to the new investors of job shops who could not afford the usage and purchase of sophisticated accounting software.

2. Literature Review

2.1. Investment Theory: Internal Funding

An investment theory is a concept that considers a wide range of factors to determine how to go about choosing suitable investments for a particular goal or purpose (Tatum, 2022). There are different types of investment theories postulated by economists, among which are; accelerator theory, neoclassical theory and internal funding theory of investment (Karmakar, 2015). In line with the Pecking order theory, companies choose to exhaust internal sources of capital before considering external sources (Nuswandari, 2013); hence, this study adopts the theory of internal funding, which is mainly accomplished by retained ploughed back earnings.

Internal funding promotes efficient funding of working capital (Sastry & Murthy, 2019), it has no transaction and bankruptcy costs and in most cases, constitutes a significant source of finance for small scale industries (Thirumalaisamy, 2013). When there are constraints in exploiting external sources of funding internal funding becomes the best and sole option.

Some of the factors that could guide investment decisions on when and which of the M&E to procure include; the return on the investment, growth of the industry, financial incentives, investor's intuition and experience, minimum cost or maximum profit (Vranakis & Chatzoglou, 2012). The limitation of these factors is that they were presented in "raw" form, which could not be understood and implemented by the majority of the investors of small-scale industries due to the level of their formal education and managerial/financial management skills (Agyei-Mensah, 2012). They could not also afford to employ the services of account or industrial engineering experts due to their limited financial capacity.

Phasing of investment in M&E can be likened to a scheduling system, in which N jobs are allocated to M machines so that all jobs are processed in a manner that optimises given performance objectives (Shen et al., 2018; Yazdani et al., 2017). A comprehensive review of job shop scheduling models between 1999 and 2019 that were reported in Coelho et al. (2021) and some recent models in Xu et al. (2020), Caldeira & Gnanavelbabu (2021), Sarfaraj et al. (2021) and Liaqait et al. (2021) were directed towards process-scheduling that is, allocating jobs into available machines for various objectives under different constraints. However, investment scheduling in job shops for M&E has been rarely reported. A conceptual model for M&E investment decisions for a general production system that presented criteria like total quality management, innovation, pricing, product lifecycle, environmental management, manufacturing flexibility and management decisions is considered for the investment in M&E where the fund is not a constraint (Vranakis & Chatzoglou, 2012). Other economic criteria like net present value, internal rate of return, payback period, etc., were also reported in the literature but not specifically for a situation where fund and demand patterns are limitations (Aderoba, 1997).

Phasing in the building construction industry is splitting a large construction into smaller parts and investing in one stage at a time. This allows the investors to decide whether to continue, wait and see, or abandon the investment after each investment phase (Collan & Savolainen, 2020). For simultaneous investment in M&E and factory construction, Aderoba (1997) employed various decision rules to sequentially schedule investment on M&E and factory building using plough back earnings. However, the study did not consider the management of working capital both in the total investment cost and as part of the components for the decision rules employed in the study.

Regardless of the size and nature of the industry, working capital is very crucial to the financial success of the organisation. It has been widely reported that many small-scale industries have collapsed due to inadequate and or improper management of working capital (Atta et al., 2017; Oladimeji & Aladejebi, 2020). Working capital is a fund to meet day-to-day operating expenses for procuring raw materials, spare parts, and consumables in the industry (Oladimeji & Aladejebi, 2020). The relevance of working capital in the total investment cost of a job shop cannot be overlooked because a job shop system requires a large inventory of materials and consumables, tools and spare parts that could only be met with adequate working capital (Mahmod, 2014).

In this study, various elements that constitute working capital in job shops were quantified and integrated into the total investment cost and the model's decision-making process. Hence, the model developed in this study is unique in the sense that it incorporated a progressive, gradual investment model in M&E with phasing-in building factory space in modular form and provided for working capital such that little capital could be used to initiate the investment in job shops for further expansion through reinvested earrings. Also, the study developed user-friendly software to quicken and ease the implementation of the model.

3. Method

The objective of this model is to schedule investment in M&E and factory building such that a job shop becomes fully functional as soon as possible. The initial capital available and continued augmentation of this from ploughed back earnings is used as an investment fund to cater for working capital, purchase of M&E and factory space construction. The assumption is that the final layout of the shop is known, all the data concerning each M&E, the factory building and the working capital are well known before the commencement of the project, and also the effect of inflation is assumed to be negligible during the gestation period of the investment.

The strategic decision to be taken is how the investment in M&E and buildings can be phased with little available capital to minimise the total project completion time.

3.1. Investment equation

A machinery item (m) purchased in period (t) incurs an investment cost c_{mt} while space A_t constructed in that period has a unit cost of K_t. The total working capital needed by period t is TWC_t. In general, the total investment (E_t) at any period t is given by following Eq. 1.

$$\mathrm{E_t = K_t A_t + \sum_{m=1}^{M} c_{mt}\alpha_t + TWC_t} \quad (1)$$

Where,

$\alpha_{mt} = 1$ if machine m is already installed by period t

$\alpha_{mt} = 0$ if otherwise

3.2. Ploughed-back earnings equation

The ploughed back earnings in period t, (R_t), is from all the machinery already purchased and put into use by period t and is given by following Eq. 2:

$$R_t = \sum_{m=1}^{M} r_{mt}\theta_{mt} \quad (2)$$

Where:

r_{mt} = returns generated by machine m in period t

θ_{mt} is a binary variable representing whether a machine has been purchased and installed by the beginning of the period (t) or not. It has the value of 1 if machinery item m has been purchased and ready for use by the beginning of period t and equal to 0 if otherwise.

The relationship between α_{mt} and θ_{mt} is shown in Eq. 3.

$$\theta_{mt} = \sum_{j=1}^{j=t-1} \alpha_{mt} \quad (3)$$

3.3. Investment constraints

Two major constraints have to be considered in this model. They are; the availability of investment funds for fixed assets and working capital and the availability of factory space for the machinery purchased.

3.3.1. Investment funds for fixed assets and working capital

The value of F_t, the capital available for investment in period (t), is the sum capital available in period (t-1) that is F_{t-1} and returns from ploughed-back earnings (R_{t-1}) in that period less the total expenditure (E_{t-1}). Therefore F_t mathematically can be expressed in Eq. 4.

$$F_t = F_{t-1} + R_{t-1} - E_{t-1} \tag{4}$$

The capital available for investment in period t (F_t), must be greater than or equal to the total investment at period t (E_t). This constraint is expressed in Eq. 5.

$$F_t \geq E_t \tag{5}$$

3.3.2. Factory space constraints

The constraints to be considered for factory space are of two types; availability of space for machinery to be purchased and maximum factory space available.

a. Availability of space for machinery to be purchased

This constraint ensures that there is enough factory space for the installation of the machinery purchased at any particular period. That is (Eq. 6).

$$\sum_{m=1}^{M} a_m \theta_t \leq \sum_{j=1}^{j=t} A_j \qquad \forall t \tag{6}$$

a_m = space required by machine m and
A_j = amount of factory space constructed in period j

The construction of the factory space (A_j) in period t will be in modular form (b_tQ) where b_t is an integer that can take any of the values 0, 1, 2, 3. Q is the incremental, modular space that specifies the standard minimum size of the building space that can be constructed at once. Therefore (Eq.7),

$$A_t = b_t Q \tag{7}$$

b. Maximum factory space available

The total factory space built at any period t must be equal or less than the maximum factory space available (Ω). This is shown mathematically in Eq. 8.

$$\sum_{t=1}^{T} A_t = \Omega \tag{8}$$

3.3.3. Objective function

The objective of this model is to ensure that the job shop is fully equipped; that is, all the machinery and equipment items (M) intended to be installed must have been installed within the shortest possible time. In terms of machinery acquisition and factory building construction, all machinery must be purchased and accommodated at the earliest possible time T. This objective is expressed in Eq. 9.

Min T:

Such that

$$\sum_{m=1}^{M} \theta_{mT} = M \qquad (9)$$

Where "T" is the project completion time.

3.3.4. Estimation of job shops working capital

This section describes the estimation of working capital as applicable to job shops in most developing nations. Various major elements of working capital, which can be grouped into four classes, were highlighted in Ismail (2017). These classes are: machine-dependent working capital (MWC) building-dependent working capital (BWC), raw material cost (RMC) and government levies, taxes and miscellaneous items (G).

a. Machine dependent working capital (MWC)

This working capital includes: Labour costs (L_{mt}), Overhead cost (which is X_t % of labour cost), Cost of electricity, Cost of insurance (Y_t % of machine cost) and Maintenance cost (V_{mt}% of machine cost).

Machine dependent working capital by period t can then be mathematically expressed as Eq. 10.

$$MWC_{mt} = \sum_{m=}^{M} \{(1 + X_t)L_{mt} + (e_t h_{mt} p_{mt}) + Y_t c_{mt} + V_{mt} c_{mt}\} \qquad (10)$$

Where,

h_{mt} = average working hours for machine m in period t

p_{mt} = power rating of machine m in period t

c_{mt} = cost of purchasing machine m in period t

e_t = cost of unit kWh of electricity in period t

b. Building dependent working capital (BWC)

This working capital includes building maintenance, lighting, water supply, etc. It depends on the size of the factory and can be expressed as a percentage of the cost of building the factory space. Mathematically, building working capital by period t is following Eq. 11.

$$BWC_t = Z_t K_t \sum_{n=1}^{t} A_n \qquad (11)$$

Where,

A_n = the total building space by period t

Z_t = the percentage of building cost for utilities in period t

K_t = the construction cost of a unit factory space in period t

c. Raw material cost (RMC)

The cost of acquiring raw material is part of the working capital, which depends on the type and nature of the job. In a job shop, the bulk of the operations performed depend on the demand of the customers. Hence, the customers often provide the bulk of the raw materials needed for such jobs through advance payment or mobilisation fees.

d. Government levies, taxes and miscellaneous expenses (G)

This is the tax or other charges paid to the Government as company tax. It can also be a royalty paid to the landowner or other facilities rented.

In summary, the total working capital in period t is given as following Eq. 12.

$$TWC_t = MWC_t + BWC_t + RMC_t + G_t \tag{12}$$

By substituting Eq. 10 and 11 in Eq. 12, it becomes Eq. 13.

$$TWC_{mt} = \sum_{m=}^{M}\{(1+X_t)L_{mt} + (e_t h_{mt} p_{mt}) + Y_t c_{mt} + V_{mt} c_{mt}\} + Z_t K_t \sum_{n=1}^{t} A_n + RMC_t + G_t \tag{13}$$

1. When this equation is incorporated into Eq. 1, the total investment (E_t) becomes Eq. 14.

$$E_t = K_t \sum_{n=1}^{t}\{(1+Z_n)A_n\} + \sum_{m=}^{M}\{(1+X_t)L_{mt} + (e_t h_{mt} p_{mt}) + Y_t c_{mt} + V_{mt} c_{mt}\} + Z_t K_t \sum_{n=1}^{t} A_n + RMC_t + G_t \tag{14}$$

3.3.5. Decision rules for M&E investment scheduling

In scheduling the investment, six (6) economic decision rules were developed and tested to know the most suitable rule(s) that will give the least completion time (T). These decision rules are:

Least machine cost at period t (c_{mt})

Least space requirement of machine (a_{mt})

Highest value of machine return (r_{mt})

Highest value of return on investment on machinery (r_{mt}/c_{mt})

Highest value of return on investment on machinery and building ($r_{mt}/\{c_{mt} + Ka_m\}$)

Highest value of return on total investment $\{r_{mt}/(c_{mt} + Ka_m + TWC_t)\}$.

3.3.6. Model solution

a. Development of heuristic

The model developed in this study has an objective function that is not linear and not directly expressed in terms of its decision variables. Due to this nature, Branch and Bound techniques or any common scheduling solutions could not be applied (Aderoba, 1997). Hence, a heuristic developed by Aderoba (1997) was modified to simulate the solution for the model. The heuristic is presented as Appendix 1.

b. Development of JOBINVEST-2021 software

To ease the implementation of this model, customised software (JOBINVEST-2021) was developed using Microsoft Excel VBA. This application was chosen for the development of the software due to its availability. The users do not need to install any special application because the application is readily available on the major versions of the Microsoft package. The software contains six windows. These windows are:

c. Main menu

This window allows the users to navigate through other windows (Figure 1).

Figure 1. JOBINVEST-2021 main menu window

d. Factory data input

This window allows the users to input factory data like; Total available space for the factory, cost of building a unit size of the factory, initial factory space available (Figure 2).

Figure 2. JOBINVEST-2021 factory data window

e. Machine/equipment data input

This window allows users to input data related to each of the M&E. These data are; Equipment/machine description, area occupied, energy consumption/hr, cost of purchasing/installation, monthly salary of manpower attached, monthly return, and average machine working hours/month (Figure 3).

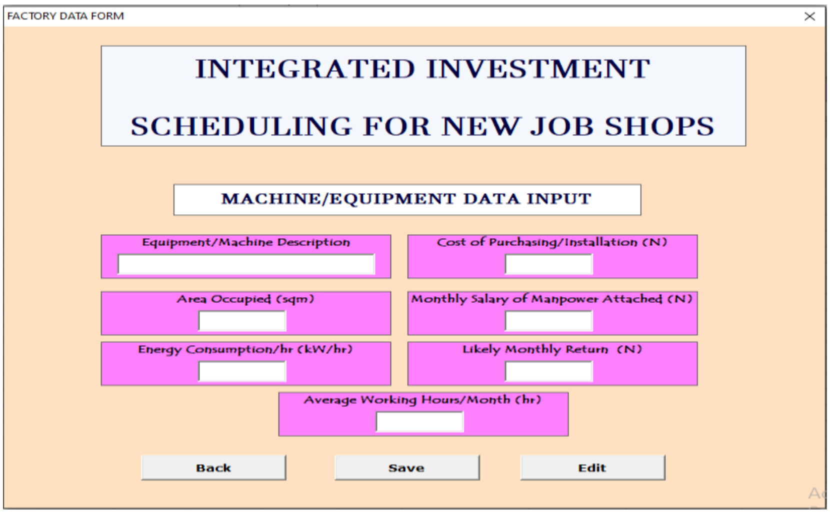

Figure 3. JOBINVEST-2021 machine & equipment data input window

f. System/investment data input

This window allows users to input data like; Government Tax/Royalties, unit rate of energy/electricity, raw material/inventories cost, the percentage for overhead cost, the percentage for insurance, percentage for equipment maintenance and percentage for factory utility (Figure 4).

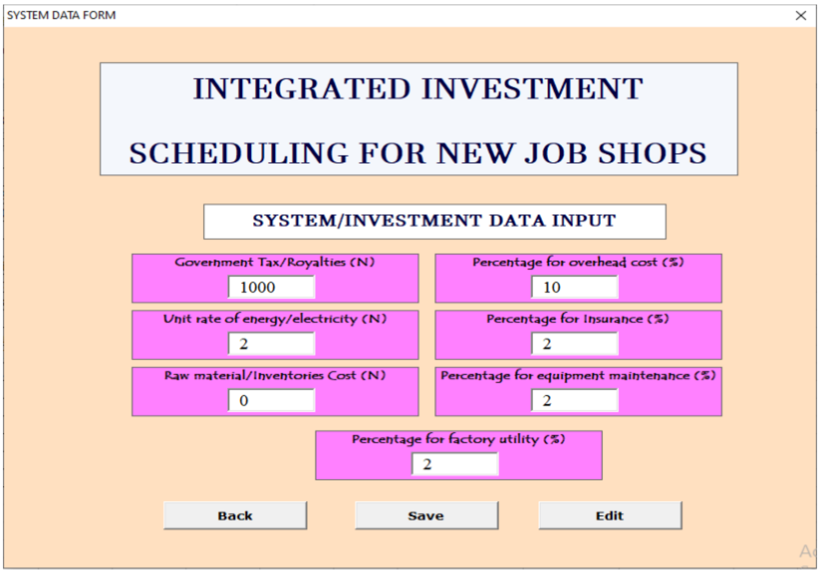

Figure 4. JOBINVEST-2021 system & investment data input window

g. Variables input/scheduling

Through this window, users can input variables like; modular building unit, initial capital and all the six decision rules. This is shown in Figure 5.

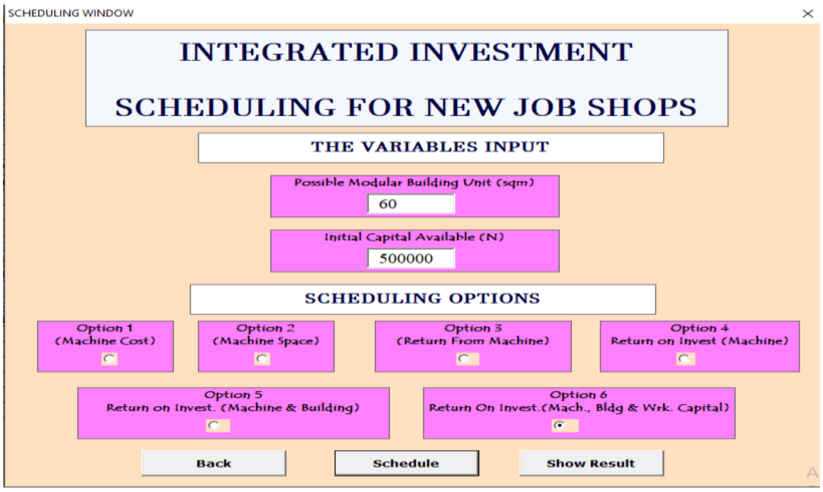

Figure 5. JOBINVEST-2021 variables input window

h. Result summary

This window displays the completion time, remaining capital, initial capital used, and the modular building increment for each decision rule. It also shows the best decision rule based on the least completion time (Figure 6).

Figure 6. JOBINVEST-2021 result summary window

4. Model Validation

The model was validated using data collected from a machine shop project under construction. The data was previously employed by Aderoba (1997) to schedule investment in M&E and factory building simultaneously. The current data updated that of Aderoba (1997) by including cost items for determining the working capital for the project. The data are presented in Table 1 and Table 2. The company planned to install eight different types of machinery with five hundred thousand Naira (N500,000) as the initial capital. This money could not be enough to execute the project at once. The total amount needed for the project, which is N1,275,194 comprises N630,000 (49.40%) for building, N596,000 (46.74%) for machinery and N49,194 (3.86 %) for the total working capital. This project can only be executed if the investments in building and machinery are scheduled over a period of time using additional capital from the ploughed back earnings.

Table 1. Machine data

Machine code	1	2	3	4	5	6	7	8
Description	Lathe	Milling	Welding	Drilling	Grinding	Painting	H/saw	W/bench
Floor space Reqd. (m^2)	30.60	23.40	21.60	14.40	9.00	30.60	19.80	30.60
Cost of Machinery (₦). 000	250	270	6	15	12	15	25	3
Net return (₦). 000	30	25	15	8	6	12	10	2.5
Power Rating (kW)	11.00	5.50	7.00	1.50	0.54	0.45	0.50	0.00
Av. Work. Hr. (Qtr/(hr	360	360	300	300	300	300	300	360
Labour cost (₦)	1,000	1,000	1,000	750	750	750	750	800

Table 2. Factory data

	CODES	VALUE
Initial floor space (m^2)	SO	0.00
Total building space available (m)	Ω	180.00
Initial capital available (₦)	FO	500,000
Cost of building a unit square meter of factory building (₦)	K_t	3,500
Incremental modular space (m)	Q	60
Taxes and miscellaneous	G_t	1000
% for overhead cost	X_t	10
% for insurance cost	Y_t	2
% for utility cost	Z_t	2
% for maintenance cost	V_{mt}	2
% for raw material cost	RMC_t	0
Cost of unit (kWh) of electricity (₦)	e_t	2

5. Result and Discussion

5.1. Result

The software prepared the criteria for the scheduling of the M&E based on the six rules. See Table 3, using these rules one after the other; it determines the project completion time (T) for each rule. Rules 1 and 2 are sorted in ascending order, while rules 3, 4, 5 and 6 are sorted in descending order. For illustration, using rule 1, the workbench with the least cost of M&E will be scheduled first, and the milling machine with the highest cost of M&E will be scheduled last. Also, for using rule 6, welding with the highest return on investment (M&E, building and working capital), 0.17, will be scheduled first. The workbench with the least return on investment (M&E, building and working capital), 0.02 will be scheduled last.

Table 3. The six scheduling rules

Machine Name	Rule 1 (Cost of M&E)	Rule 2 (Area of M&E)	Rule 3 (Returns from M&E)	Rule 4 (ROI-M&E)	Rule 5 (ROI-M&E+B)	Rule 6 (ROI-M&E+B+WC)
Welding	6,000	21.60	15,000	2.50	0.18	0.17
Workbench	3,000	30.60	2,500	0.83	0.02	0.02
Painting	15,000	30.60	12,000	0.80	0.10	0.09
Drilling	15,000	14.40	8,000	0.53	0.12	0.11
Grinding	12,000	9.00	6,000	0.50	0.14	0.13
Hacksaw	25,000	19.80	10,000	0.40	0.11	0.10
Lathe	250,000	30.60	30,000	0.12	0.08	0.08
Milling	270,000	23.40	25,000	0.09	0.07	0.06

The result of scheduling using all the six decision rules with the initial capital of N500,000 and incremental modular space of 60m^2 is shown in Table 4.

Table 4. The result of scheduling using the six decision rules with N500,000 initial capital

	Project completion time (T) at FO-N500,000 and Q at 60 m²					
	Rule 1 (Cost of M&E)	**Rule 2 (Area of M&E)**	**Rule 3 (Returns from M&E)**	**Rule 4 (ROI-M&E)**	**Rule 5 (ROI-M&E+B)**	**Rule 6 (ROI-M&E+B+WC)**
Project Completion Time	25	26	37	25	24	24
Balance after Completion of Project	26,290	11,760	72,290	31,710	96,010	96,010

A sensitivity analysis of the results was done by varying the value of incremental modular space Q to determine the effect on the project completion time T. This is shown in Table 5. Also, Table 6 shows the effect of varying the initial capital with various incremental modular space Q.

Table 5. Sensitivity analysis for variation in space modularity (Q)

	Project completion time (T) at FO-N500,000					
Q (m²)	**Rule 1**	**Rule 2**	**Rule 3**	**Rule 4**	**Rule 5**	**Rule 6**
30	24	23	32	24	21	21
45	24	24	37	24	22	22
60	25	26	37	25	24	24
90	29	24	n.p*	29	27	27
180	n.p*	n.p*	n.p*	n.p*	n.p*	n.p*

n.p*= not possible due to insufficient initial capital (FO).

Table 6. Sensitivity analysis for variation in initial capital (FO)

	Project completion time (T) using Decision rule 6		
Q (m²)	**FO= N500,000**	**FO= N750,000**	**FO= N1,000,000**
30	21	14	7
45	22	14	8
60	24	16	9
90	27	17	9
180	n.p*	18	10

n.p*= not possible due to insufficient initial capital (FO).

5.2. Discussion

The result of scheduling in M&E with an initial capital of N500,000 and 60m^2 space modularity using the six decision rules (see Table 4) shows that decision rule 5 and 6 give the least project completion time of 24 with the highest leftover of N96,010. Next to this is decision rule 4 and 1, while decision rule 3 (decision-based on the returns from the M&E) gives the worst completion time of 37. This result shows that return on total investment is a good option for this job shop to schedule investment in M&E with little initial capital. At the same time, it is unwise to schedule the investment for this job shop using the expected income from the M&E, which has been a traditional option for most investors in M&E (Udoayang et al., 2020).

The result of sensitivity analysis for variation in space modularity, as shown in Table 5, reveals that the least completion times could be obtained with less value of Q with the initial capital of N500,000 and an attempt to construct the factory building at once (180 m^2 of Q) with the initial capital of N500,000 could not be achieved (i.e. not possible).

As shown in Table 6, if the initial capital is increased, there is a reduction in the project completion time and gives room for the completion of the factory building at once. There is little effect on the completion time when there is an increase in modularity with high initial capital. The sequence and project completion period for both Option 5 (schedule based on Return on Investment when machine and building are considered) and (schedule based on return on total investment) are the same. This may be because working capital itself is a function of the cost of machinery and the cost of the factory building.

6. Conclusion

In the developing nations, job shops are mostly small-scale industries and their establishment is greatly hindered by the lack of sufficient capital to start the investment in one fell swoop and commercial banks hardly give them loans due to their nature of not having a predictable production target. Considering the relevance of small-scale industries and, most especially, job shops to the economic and technological development of a nation, this study developed an integrated investment model for the establishment of new job shops that could not afford the huge capital needed for the acquisition of M&E, construction of factory building and the recurrent working capital.

The model developed in this study was formulated to employ little capital to embark on the establishment of job shops by scheduling the acquisition of M&E gradually with a phase-in approach for the construction of factory building on a modular basis using six different decision rules for the scheduling. The investment theory employed is an internal funding approach whereby the capital was gradually augmented through ploughed back earnings from the acquired M&E. The project completion times from these six decision rules were compared, and the best decision rule that gives the least project completion time was determined. The study also developed software using Microsoft Excel VBA to ease the implementation of the model. This model is expected to assist any interested investors in job shops to select the best option in investing in M&E when there is little capital to commence the project at once.

7. Recommendations and Limitations

In using this model, care must be taken to use reliable data because the results obtained from this model greatly depend on the nature of the data. There is also a need to carefully determine the value of Q, the modular space, to reflect architectural and economic values. Further study could be done to incorporate a model that will forecast sales in job shops, consider the inflation rate and also take into consideration the sequential layout of the factory to account for technological interdependence among the M&E. This model is highly recommended for intending investors in job shop investment, particularly in developing countries.

It should be noted that the results obtained for this case study may be different from another case study because the result depends solely on the nature of the data. Hence reliable data should be sought when applying this model.

Authors' Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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Appendix 1. The heuristic to simulate the solution for the model.

SYSTEM DATA INPUT

STEP 10: input the general factory data: - K_t, m, M, p_m, Q, Ω, SO

STEP 20: input all the machinery data: -a_m, c_{mt}, h_{mt}, L_{mt}, r_{mt}

STEP 30: input all other constants: - e_t, FO, G_t, X_t, Y_t, Z_t, V_{mt}, RMC_t

DECISION RULES FOR MACHINE SELECTION

STEP 40: calculate the decision index for all machinery.

STEP 50: arrange the machinery according to the decision rule and open a file for it.

SYSTEM INITIALISATION

STEP 60: set time t=0

STEP 70: set $\alpha_{mt} = 0$, $\theta_{mt} = 0$, $b_t = 0$, at = 0 for all m and t

MACHINERY SELECTION AND DEVELOPMENT PROCEDURE

STEP 80: increase t by 1

STEP 90: select the first machine on the list of file OPTION

STEP 100: calculate ploughed back return available from the preceding period (R_{t-1})

STEP 110: update investment fund i.e. $F_t = F_{t-1} + R_{t-1}$

STEP 120: determine the minimum additional space to accommodate this machine i.e. (bt =0, 1, 2, 3,…)

STEP 130: if the available fund is insufficient to purchase machinery, built space, cater for total working capital by period t (i.e. $F_t < E_t$) GOTO STEP 200

STEP 140: purchase this machine in this period i.e. $\alpha_{mt} = 1$

STEP 150: review building space to be constructed in this period i.e. increase A_t, by btQ

STEP 160: upgrade available space "SO" by "b_tQ" less "a_{mt}"

STEP 170: reduce available funds by E_t,

STEP 180: upgrade machinery status to purchase, installed and provide for its working capital that is $\alpha_{mt} = 1$

STEP 190: remove machinery from the file and GOTO STEP 210

STEP 200: set $\alpha_{mt} = 0$ i.e. do not purchase this machine at this period GOTO 80

STEP 210: if the present candidate machinery is the last on the list in FILE OPTION GOTO STEP 230

STEP 220: select the next machinery on the list in the FILE OPTION, GOTO STEP 120

STOPPING RULE

STEP 230: if the file OPTION is empty, GOTO STEP 250

STEP 240: GOTO STEPS 80

STEP 250: set T (the scheduled time for full factory functionality =1)

STEP 260: print T and the schedule $\{\alpha_{mt}\}$, A_t

STEP 270: STOP