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A Decision Support System for Course Materials Production and Inventory Management in the National Open University of Nigeria

Peter I. Adoga [1] , H.G Muazu [2], M. Barma [2]

[1] ICT Directorate,
National Open University of Nigeria,
Otukpo Study Centre,
Benue State.

[2] Department of Statistics and Operations Research,
Modibbo Adama University,
Yola, Adamawa State,
Nigeria

Email: padoga@noun.edu.ng

Abstract

This paper focuses on the design of a Decision Support System for Course Material production and inventory management in the National Open University of Nigeria. The proposed system has a model base management subsystem which is a component that differentiates Decision Support Systems from other types of Information Systems. The model base consists of a wide collection of models which include inventory models, production quantity models and a forecast model. Other components of the system including the data management subsystem, dialog generation and management subsystem and the users of the system were also discussed. A prototype of the Decision Support System was developed using python programming and MYSQL database server. Testing and validation was done using sample data of students' enrolment and user defined inputs for the forecast, inventory and production modules of the system. The results of the tests show high level of accuracy when compared with those obtained from manual computations. The design is simple, flexible and can be easily modified to suit the needs of other institutions with multi-item inventory problems.

Keywords: Decision Support System, inventory, Model base, Production, Python Programming.

INTRODUCTION

As business models of firms, government institutions, Universities and other organizations get more complex, there is increased need for information systems that can support the diverse information and decision making needs of the staff and managers of these firms. Although many attempts have been made by specialized business solution providers to develop enterprise applications for business owners, the complexity and diversity of these generalized solutions, makes them difficult to use and hence most times reduce their profitability to individual firms. Most firms hence prefer Decision Support Systems (DSS) developed specifically for them using their information requirements and business models. O'Brien (2004) defined DSS as computer based information systems that provide interactive information support to managers and business professionals during the decision-making

**Author for Correspondence*

process, through the use of analytical models, specialized databases, a decision maker's own insight and judgment and an interactive computer-based modeling process to support the making of semi-structured and unstructured business decisions. Specialists have discussed building DSS in terms of four traditional components namely: The user interface, the database, the models, and lastly, the architecture and network (Sprague and Carlson, 1982 cited in Power, 2015). Hasan et al. (2016) and Marek & Roger (2010) identified Data Management Subsystem, Model Base Management Subsystem and Dialog Generation and Management Subsystem as three essential components of every decision support system. Marakas (2003) added The Knowledge engine and the Users as two additional components that must be considered when designing a DSS.

Power & Sharda (2007) discussed model-driven DSS built using decision analysis, optimization, and simulation technologies. Arica et al. (2014) proposed a framework for designing decision support systems for scheduling activities in complex and uncertain manufacturing environments. Jiang (2020) developed a DSS driven by internet of things (IoT) to provide solution for intelligent and collaborative production and distribution processes. Shirazi et al. (2010) presented a simulation based intelligent decision support system for real time control of a flexible manufacturing system with machine and tool flexibility. Hajalalaina & Andriniaina (2021) proposed a spatial analysis system of agricultural production using the spatial data warehouse technique. Abubakar et al. (2020) developed a linear programming model to aid production companies in profit maximization. The model was solved using Microsoft Excel solver and PHP simplex. Chang (2010) developed a Web-based DSS for cell formation problems which enables production practitioners to obtain optimum results without much expertise. Gustriansyah et al. (2015) developed a DSS for inventory management in pharmacies, to predict next inventory using Fuzzy Analytic Hierarchy Process and Sequential Pattern Analysis. Parekh et al. (2008) developed an Integrated Inventory Ranking System for inventory management that is useful in solving the problem of subcontracting vs. manufacturing locally. Giachetti (1998) described a material and manufacturing process selection system that integrates a formal multi-attribute decision model with a relational database.

Managing the complex processes involved in production and Inventory control using human intuitive judgment and manual processes is undoubtedly daunting with too many associated challenges. More so, these manual processes most times produce unreliable outputs which lead to wastages, extra costs and other disadvantages compared with automated systems. A study of the system of Course Materials production planning and inventory management in the National Open University of Nigeria (NOUN) shows that a lot of problem-solving and decision-making processes are manually carried out. This has effect on the overall productivity and efficiency of the resultant system as evident in the non-availability of some Course Materials at the Study Centres when demanded by students. A major weakness of the existing system is the absence of an integrated system that should bring all the people involved in Course Material production and inventory management together, for enhanced decision making and better outputs. Such system should be a computer based Decision Support System with wide collection of models to solve problems across the different units of the workflow.

MATERIALS AND METHODS

Analysis of the New System

The proposed new system is an automated model driven and computer based Decision Support System, which will help to reduce overdependence on human intuition and manual computations throughout the process of inventory and production management of course materials in NOUN. The system consists of four basic modules designed to handle specific aspects of the problem:

1. The students' enrolment forecast module is designed to forecast enrolment of students into the various programmes of NOUN. This enrolment numbers are required to compute the estimated demand for each Course Material. The module uses the Holt Winters Additive (HWA) model to forecast student enrolment in a succeeding year.
2. The Study Pack module is designed to compute the estimated demand of Course Materials required to service demand of students in a forecast year. Study pack refers to the list of courses offered by students of each programme and level in the institution.
3. The Inventory Management module is designed to manage inventory under three basic constraints common to most organizations.
4. Finally, the Production module is designed to manage production whenever there is need to produce rather than to order from other sources.

These modules were all built into a single decision support system with friendly interfaces for all categories of users.

Model Specification

Here we specify the models used in the design of the Decision support system.

Data Management Subsystem (DMS)

The Data management subsystem stores the data required to run other components of the system. The SQLyog community edition which uses the MSQL Graphical User Interface (GUI) was used as the DMS in the DSS prototype. Our database consists of two types of tables and several queries as shown in table 1. The system depends on inputs from the first type of table named Rc_demand to run while the second type of table stores outputs and has a user defined name (e.g 2023_cm_forecast). The database can contain many of the user defined tables depending on how many times a user decides to save the output of the system. Table 1 also shows query functions used in manipulating entries in the database. The query functions receive data requests from users through the GUI of the DSS, process the requests and return the results as outputs or backend operations.

Table 1: Components of the DMS

S/N	Component	System specified name	Sub-components/fields	Definition and function
1	Database	Hwa_project	Table1, Table2..	Collect and stores data
2	Table 1	Rc_Demand	• Course_code • Course_title • Unit • Status • Level • Semester • Programme • Forecast_Demand	Stores data of courses offered by students at different levels of a programme
3	Table 2	2023_CM_Forecast	• Course_code • Forecast_Demand	Stores forecast demand for a forecast year
4	Queries	Query1, Query2….	• SELECT Statements • UPDATE Statement • GROUPBY Statement • CREATE TABLE Statement	Receive data requests, process the requests and return the results

Model Base Management Subsystem (MBMS)

The model base management subsystem provides all the necessary support for the execution of the model libraries in the DSS. The Model base is the major component that differentiates a DSS from other information systems, so much time and resources were dedicated to this aspect of the design and implementation of the DSS. The model base of the DSS in this research consists of four specialized models; The Holt Winters additive forecast model, an algorithm to compute demand (the study pack algorithm), inventory models and economic production models.

These Models were executed using modeling tools provided by dedicated python programming libraries. The python libraries include numpy, pandas, maths, matplotlib, sklearn.metrics, statsmodels.tsa.holtwinters and pymysql. Within the python programme, each model is cataloged and placed in a separate Menu for easy identification. The models are executed by simple click activities carried out by the DSS users. Table 2 shows the specific functions of each model. Adoga et al. (2022) presented a detailed design of the models.

Dialog Generation and Management Subsystem (DGMS)

The Graphical User Interface provided in this research work to help users interact with the system is no doubt one of the most fascinating aspects of work. The GUI prototype was designed using tkinter library of python programming language. Python projects like Django can be used to implement a Web solution if the users are separated by a wide distance. The menu interface style used in this work offers flexible and easy to use interfaces for all categories of users. The interfaces and the roles they play in the designed system are discussed in the result section.

The Users

Users are major component of the system which drives other aspects of the system through application of their knowledge and performance of their assigned roles. The DSS has two basic categories of users; those with specialized knowledge of the problems which the DSS is designed to solve and those with the knowledge of the DSS application software. In the first category, we have staff who perform tasks such as data entry, problem formulation and model building to allow the mangers or major decision makers concentrate on the advance unstructured aspect of decision making. The second category is made up of technical staff whose major role is to ensure that the software and hardware components of the DSS are completely setup and to assist other users in areas where they may lack the technical knowledge to perform their assigned roles. The proposed system is designed for users across five different units of the institution with each playing a unique role as shown in table 3.

Hardware Requirement

The following hardware are required for the implementation of the Decision Support System:

- A host server for the application
- A LAN connecting all client computers to the server
- Client computers at various user ends.

Table 2: Components of the Model Base Management Subsystem

S/NO	Model	Model Type	Sub-components	Definition and function
1	Holt Winters Additive Model	Forecasting Model		Forecast students enrolment for a forecast year
2	Study Pack algorithm	Mathematical Model		Compute the total number of Course materials that will service the demand of forecast number of students
3	Inventory Models		• Model with space constraint • Model with monetary constraint • Model with inventory items constraint	Use to compute the EOQ, Optimum number of orders and cost of inventory items
4	Production Models		• Economic Production Quantity (EPQ) Models.	Use to determine production variables such as EPQ, total cost of items per production run, production cycle and number of production in a year.

Table 3: Users and Their Assigned Roles in the DSS

SN	Staff Unit	Assigned roles in the designed DSS
1	The Management Information System Unit	Users in this unit will perform the task of obtaining and uploading time series data of students' enrolment. This data is needed to run the Holt Winters Forecast model base of the system. The specific tasks of staff of this unit are to: update the time series every semester, arrange it in the system specified format and upload it using the interface provided in the DSS.
2	Departmental Course Registration officers	At the departmental level, the study packs are organized and uploaded into the DSS. The study pack algorithm requires this data to run. The specific task of staff of this unit is to update the study pack of each programme.
3	The Procurement Unit	This unit is responsible for providing data such as the setup cost, holding cost, production rate and amount of money available for investment on inventory items. This data is required to operate the inventory and production model bases of the DSS. The specific tasks of staff of this unit are to obtain the yearly forecast demand for each Course Material and then provide the required variables needed to obtain results for each Inventory and Production Model.
4	The Store Unit	This unit in collaboration with the Procurement unit executes the Inventory and Production Models by applying relevant constraints and job expertise. The outputs guide them to make requisitions for optimum quantities of inventory items and to monitor the stock level to know when to place the next requisition. The major decision makers of this system are from this unit.
5	The Technical Unit	The task of the technical unit is basically to ensure that all software and hardware required by the system are available and up-to-date. They also manage the SQL database component of the DSS. Staff of this unit should have a good knowledge of the operations of the DSS so as to be able to train new users and help existing ones in areas of their difficulties.

System Implementation

Jupyter notebook provided the flexible Integrated Development Environment (IDE) used in the development of the DSS using python programming language. The Python pandas library was used to handle the large data used in the design. The statsmodels.tsa.holtwinters library was used for forecasting future values of students' enrolment, while pymysql library was used to handle the SQL database operations. The maths and sklearn.metrics libraries provided tools for coding of the mathematical and statistical equations while the Tkinter library was used to develop the GUI.

The various modules of the DSS were tested to determine the performance and accuracy of the system. The HWA forecast module was tested using data of students' enrolment into three programmes (p_1, p_2 and p_3) as a prototype of other programmes in NOUN. The study pack module was also tested using the obtained forecast values for p_1, p_2 and p_3. The module accurately generated quantities of each Course Material required to service students' demand within the forecast period. The Inventory and Production modules were tested using the demand quantities obtained from the study pack module and other user defined inputs. Results showed high accuracy and timeliness of outputs compared to manual computations.

RESULTS AND DISCUSSION

The Holt Winters Additive model, Inventory models, study pack algorithm and the production models specified in table 2, were integrated into a single Decision Support System, with a separate menu designed to accommodate each of them. The components and tools of the resultant DSS prototype are discussed below:

- The Home Screen: This page contains all the menus from where a user can select a suitable tool. The Menus are: File, Forecast Models, Inventory Models, Production Models, Study Pack and Tools menus.
- Forecast Models Menu: This Menu contains tools used for executing the HWA forecast module of the DSS. Figure 1 shows the interface of the HWA forecast module. The interface consists of an input window which displays the model inputs imported by the user, a tool for executing the HWA model and an output window which displays the outputs of the system. The module enables a user to select an input file containing time series data of students' enrolment into different programmes of the Institution for a given period. The selected input file is then displayed in the input window for the user to preview before executing the model. When the HWA model is executed, the outputs are displayed in the output window as shown in figure 1. Results of the HWA model are further used to compute the demands for various Course Materials in a forecast period.

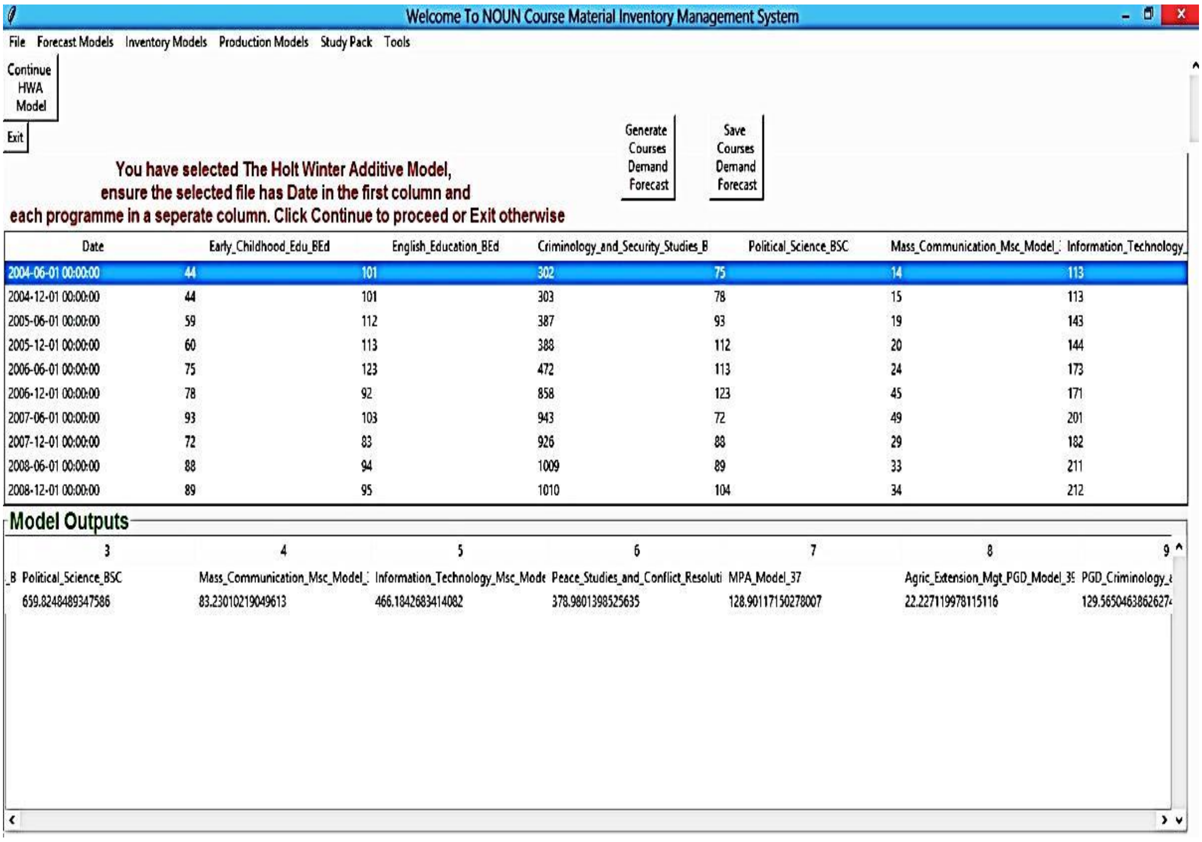

Figure 1: Input and output of the HWA Forecast Module.

- Inventory Model Menu: This menu consists of three menu items used for executing the inventory module of the DSS. It allows a user to select an input file for an inventory model and then provide tools for execution of the chosen model. Upon execution, the model outputs consisting of the economic order quantities (EOQ) of each course material, optimum number of orders per year and the total ordering cost are displayed in the model output window as shown in figure 2. The results of this module will help Decision Makers to decide on when to place orders and how much quantity of each item to order at a given time.

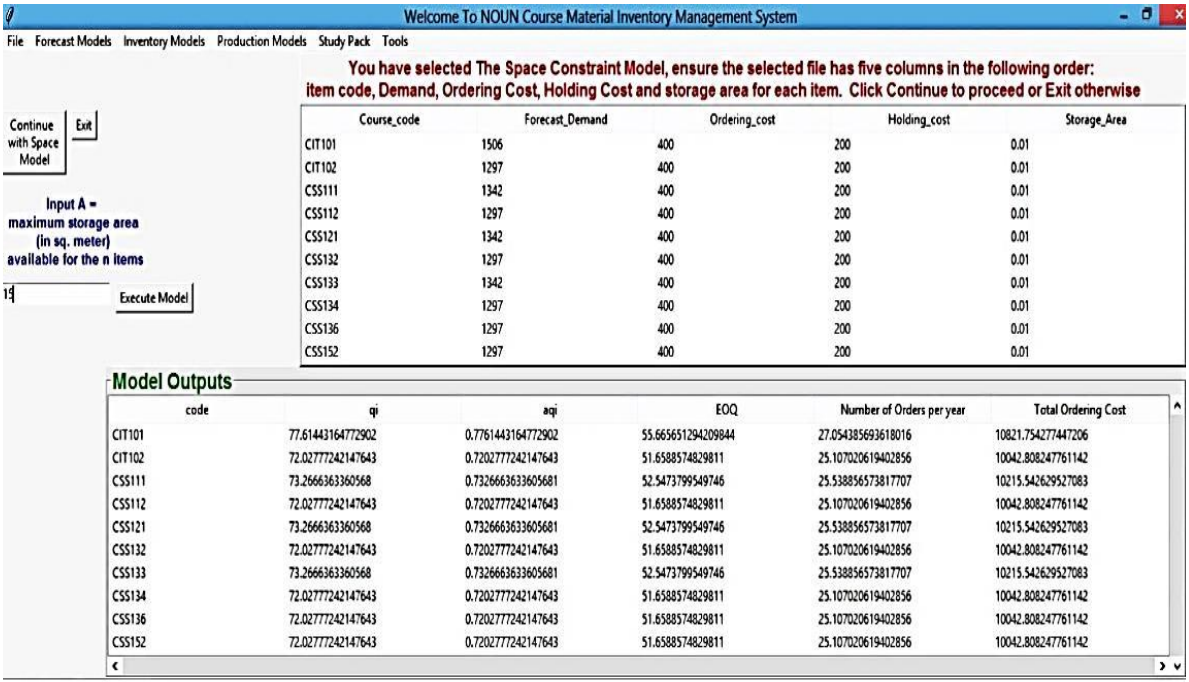

Figure 2: Inputs and Outputs of the Space Constraint Inventory Module.

- Production Models Menu. This Menu contains tools for executing the Economic Production Quantity (EPQ) module of the DSS. Figure 3 shows the interface of the EPQ module of the DSS. In the design, a user selects the production model menu to begin execution of the EPQ model. The interface then provides a filedialog to enable the user locate and import an input file which must have been prepared and saved in the client computer before the execution time. The user is allowed to preview the inputs in the GUI before executing the EPQ model. The outputs generated are then displayed in the output window at the bottom as shown in figure 3. The results of this module will help Decision Makers to determine the EPQ of each item before a production run begins. The outputs also guide the Decision Maker to decide when to produce each item and to determine the cost of items per production run.

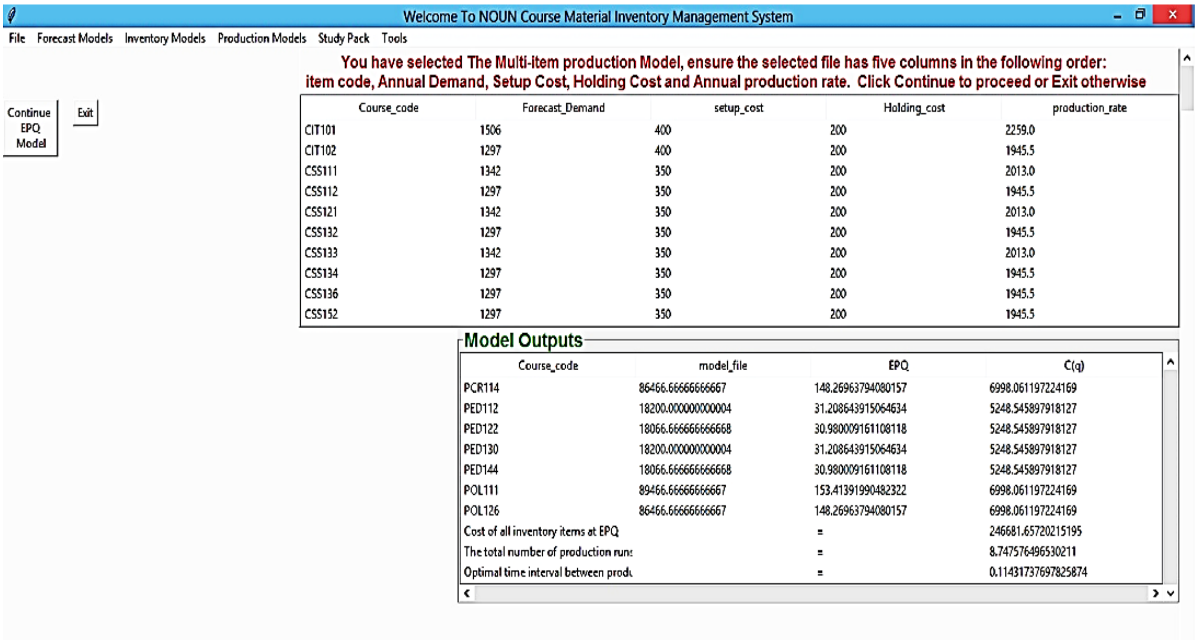

Figure 3: Inputs and Outputs of the EPQ Module.

- The File Menu: This Menu consists of four menu items: Open, Save, Export and Print. It is used for report generation and printing of outputs.
- The Study Pack Menu: This Menu consists of tools used for managing data of the study pack of each programme.
- The Tools Menu provides quick access to readily used tools.

CONCLUSION

In this research we collected and integrated several models into a single decision support system to solve the problem of non-availability of some essential study course materials when demanded by registered student of the National Open University of Nigeria. The proposed computer based decision support system when implemented will ease work for the category of staff involved in the determination of demand, production and inventory management of study course materials in the institution. It will aid in reducing the deficiencies of human intuitive judgment, reduce stress resulting from regular manual computations of complex models and enhance decision making in the institution. Combining a wide range of production and inventory models in a single DSS gives the Decision Maker the advantage of comparing the outcomes of producing locally and Ordering from other suppliers before making a choice. It will also promote innovation amongst users and managers as the choices to explore increases. The propose DSS model is simple, flexible and can be modified by institutions with similar problems to suit their needs.

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