INTELLIGENT INTEGRATED MANUFACTURING DECISION MAKING SYSTEM

Abid Thyab Al Ajeeli,
Higher Education Committee,
C.O.R., Iraq
Email: abidtj@yahoo.com

ABSTRACT

In today's highly competitive intellectual environments which force top management to constantly looking for better improvement and making the best decisions in shortest possible time and within limited resources. Managers in manufacturing companies need to have strong capability of adaptation mainly because of the dynamic relationships that must be established between manufacturing units. To achieve these, there is a need for an integrated manufacturing system that will handle all interactions and interrelationships which will then be affected by the changes and create maximum gain under heavy constraints on time, technical capabilities, finance and many other resources. This paper, addresses the problem of building intelligent computerized system that combines finished products, associated sub-assemblies, raw materials, interactive relationship activities, and/or reasoning capabilities. Systems with a high degree of computer intelligence are more robust, controllable, questionable, and lead to better optimality, and be able to perform its job more efficiently.

The proposed system provides a number of objectives including cost minimization, control over manufacturing activities, intelligent querying and answering feature capabilities. It incorporates computer intelligence in manufacturing decision making process. Computer intelligence provides high interactivity, querying facilities, and reasoning possibilities. The proposed system finds the best optimal solutions while any other combinations would lead to an increase in the total variable costs. In order to convince general readers, an evidence of optimality is provided and a number of case studies for sensitivity analysis is conducted. The finding from the conducted experiments provides opportunities that the proposed model has higher trust over the conventional ones. The proposed system is general and therefore it is applicable to most manufacturing industries.

KEYWORDS: *Intelligent system, optimal criteria, manufacturing system, production system, constraints, raw materials, finished products.*

I. INTRODUCTION

The integration concept of manufacturing processes has enjoyed increased popularity among researchers and manufacturers. Although such systems can provide better utilization of resources, they have a number of drawbacks due to complexity of real-world problems. Using intelligent technique approaches can produce better-automated systems. Intelligent techniques can be exploited to model human reasoning in order to model the intangible aspects of a system. Integration of computational intelligence can reduce subjective decisions and increase the potential for real-time automation [1]. It has capabilities for assisting, constructing, and maintaining intelligent system. This allows human expertise to be encoded in order to be used in the inference mechanism. It helps organize production processing. They produce a flexible system based on production rules [2].

This is a dynamic system where raw materials are not known in advance. Hence, the system can cater for different criteria. That is, different raw materials, different number of similar raw materials used in producing a product·

Processing a large amount of items of information about the system components, control variables, and the interdependency structures add new challenges upon management. Hence, a system that is characterized by a high degree of intelligent automated simulation is essential. The proposed system provides traceability capabilities for components and their relationships. It provides manager and engineer with sufficient items of information in order to detect inconsistencies. That is; it has reasoning capabilities on the system objects.

Previous works adopted certain tools and techniques to solve production problems but these techniques lead to a large integer problem and an inefficient implementation with some interfacing obstacles [2]. They require also complete information of the specific domain [5]. Previous works assume a number of restrictions. These restrictions on models sometimes lead to unrealistic or may not provide the optimal solutions. Queries are essential for managers to have a clear picture of their company activities. Most previous works do not provide a query system.

This paper is organized as follows: the second section describes the construction of a knowledge representation. In section three, an algorithm invocation module is outlined. It shows how modules are generated and how cost of invoked module is computed. The production system cost is introduced in section four. The section describes the building of finished product model, the raw material building model, and the combined integrated model. Section five explores the optimality criteria in mathematical terms. Constraints limitation that imposes limitation on achieving management's goal is depicted in section six. Empirical investigation is conducted in section seven by presenting a number of case studies showing the viability of the intelligent manufacturing decision system. In section eight, scientific validation of the proposed system is explained. Section nine explores interaction and querying facilities that the proposed system provides. Finally, conclusions are summarized the research activities in section ten.

II. CONSTRUCTION OF KNOWLEDGE REPRESENTATION

In order to understand how to construct a knowledge representation, one need to emphasize on the roles it plays [13]:

A knowledge representation is a surrogate, a substitute for the thing itself, used to enable an entity to determine consequences by thinking rather than acting, i.e., by reasoning about the world rather than taking action in it [13]:

- It is a set of ontological commitments, i.e., an answer to the question: In what terms should I think about the world?
- It is a fragmentary theory of intelligent reasoning, expressed in terms of the representation's fundamental conception of intelligent reasoning; the set of inferences the representation sanctions; and the set of inferences it recommends.
- It is a medium for pragmatically efficient computation, i.e., the computational environment in which thinking is accomplished. One contribution to this pragmatic efficiency is supplied by the guidance a representation provides for organizing information so as to facilitate making the recommended inferences.
- It is a medium of human expression, i.e., a language in which things said about the world.

A manufacturing of a complex product requires a wide range of knowledge and information updating. It is of great importance to know how thousands of modules (components, texts, programs, items, and/or assemblies) of the system cooperate as well as their individual effects on the overall production system. This production system, I believe, would be more efficient if a complete understanding of the behavior of all sub-systems and the relationships among them is automatically available. We explain modules of a product as modules and their related issues can be represented as *n-tuple*. Modules A_1, ..., An, where n > 1 , the Cartesian product of A_1, ..., An, denoted by $A_1 \times A_2 \times \ldots \times$ An, is defined :

$$A_1 \times A_2 \times \ldots \times A_n = \{ (x_1, \ldots, x_n) \text{ where } x_i \text{ is in } A_i \quad 1 <= i <= n \}$$

The knowledge base should incorporate component name, related items, type of component whether it is an atom, or subassembly, or final product. The knowledge should also contain responsibilities regarding each component. How the component has been manufactured, who is responsible, where its

location, to which module does it belong, how many units are available from that component, whether it is intangible or tangible and so on.
Any system can be represented as a digraph of the form in figure (1):

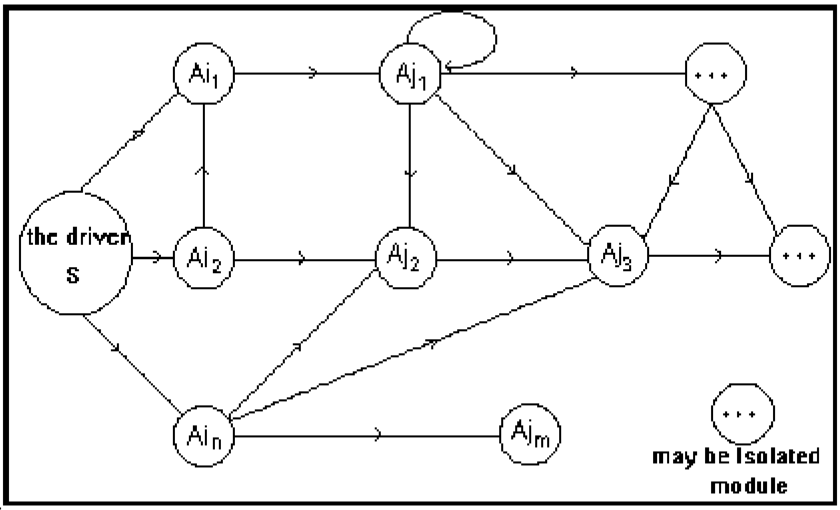

Figure 1: Digraph of nodes (modules)

Given a system, S, define a digraph G of an ordered pair G = (V, E) of vertices (modules) V and directed edges (invocation) E that belongs to the Cartesian product V×V, where V and E are finite sets. Given two modules Ai_k and Aj_r in a digraph G = (V, E), then Ai_k is a predecessor of Aj_r and Aj_r is successor of Ai_k if there is an edge (Ai_k, Aj_r) in E i.e. if and only if module Ai_k contains an invocation or call of module Aj_r . It is necessary to say that a module Aj_1 is recursive if and only if there is a cycle from Aj_1 to itself. Strictly speaking, Aj_1 is *putative* since the necessary sequence of calls may never occur in any execution of S. We associate with each module Ai_k, for all i and k, a set of attributes in factual forms inserted automatically into the proposed knowledge base.

III. MODULE INVOCATION ALGORITHM

The set of invoked modules R, that belongs to the graph G= (V, E), can be generated using the following proposed algorithm.

3.1 Module Generation Algorithm

The proposed algorithm is simple and easy. It identifies initial conditions and the main loop. It is constructed as follows:

```
Initial condition

R := {S};
x = { x: x has property P }
Total-Set := { Aik};          (*   for all i and k        *)

Main loop

repeat T:= f;                 (*   T is a temporary set    *)
       for all Ajr in total-set and Ajr is in x do
       T: = T ∪ { w ∈ (Ajr, w) is in E } ;
       Total-Set := T - R ;   (*   The new reachable nodes *)
       R : = R ∪ Total-Set
until Total-Set = f;
```

On exit, we expect the algorithm to generate all reachable modules in graph G = (V, E).

3.2 Module Invocation cost

Invocation (or calls) is, simply, a permutation of V modules where each module may be invoked zero, one, or more times.

$$\sum_{j=1}^{M} calls(Ai_k,\ \ Aj_r)$$

where 1 <= i, k, j, r <= V, M = (V -1) + Q ,

and Q is the total extra calls for all modules except the driver S. To compute the total cost, an estimation of the time required for each call, on average, can calculate. The estimated cost of a call includes searching for the right module's version, i.e. the version that satisfies the imposed conditions set up by users or even the default conditions. Suppose the estimated cost for a call is t_{call} , the total cost for building the proposed system is:

$$t_{call} \times \sum_{j=1}^{M} calls(Ai_k,\ \ Aj_r)$$

The complexity of the algorithm depends on the size of manufacturing applications being applied.

IV. CONSTRUCTION OF THE MANUFACTURING SYSTEM COST

Construction manufacturing cost control systems have been the subject of a myriad of studies. Despite their relevance in terms of both improving the cost estimate structure and the integrating cost and schedule, they have hardly contributed to the integration of cost management and manufacturing control systems. Besides the fact that construction cost control systems have not changed much since the Seventies, cost management and production control are still treated independently, as separated systems. From a managerial point-of-view, the effort to develop, implement and operate a cost system is justifiable only when the cost information provides effective support for decision making [14]. Activity-Based Costing has been increasingly adopted in many industrial and service firms as a method to improve cost management in complex manufacturing systems.

The proposed production model system has two main parts:

- the finished products model, and
- the raw materials model.

The two models are discussed in details in the following sub-sections.

4.1 Developing the Finished Product System

A product can be classified as building materials or intangible. A tangible product is a physical object that can be perceived by touch such as a building, vehicle, gadget, or clothing. An intangible product is a product that can only be perceived indirectly such as an insurance policy. Each time a batch is produced, a setup cost is incurred. This cost includes the cost of “tooling up,” administrative costs, record keeping, and so forth. Note that the existence of this cost argues for producing components in large batches. The unit production cost of a single component (excluding the setup cost) can be defined, independent of the batch size produced. (In general, however, the unit production cost need not be constant and may decrease with batch size.). The production of components in large batches leads to a large stock. The estimated holding cost of keeping a component in a stock is also can be defined per unit time. This cost includes the cost of capital tied up in inventory. Since the money invested in inventory cannot be used in other productive ways, this cost of capital consists of the lost return (referred to as the opportunity cost) because alternative uses of the money must be forgone. Other components of the holding cost include the cost of leasing the storage space, the cost of insurance against loss of inventory by fire, theft, or vandalism, taxes based on the value of the inventory, and the cost of personnel who oversee and protect the inventory [15].

The holding cost (sometimes called the storage cost) represents all the costs associated with the storage of the inventory until it is sold or used. Included are the cost of capital tied up, space, insurance, protection, and taxes attributed to storage. The holding cost can be assessed either continuously or on a period-by-period basis. In the latter case, the cost may be a function of the maximum quantity held during a period, the average amount held, or the quantity in inventory at the end of the period [16].

The shortage cost (sometimes called the unsatisfied demand cost) is incurred when the amount of the commodity required (demand) exceeds the available stock. This cost depends upon which of the following two cases applies. In one case, called backlogging, the excess demand is not lost, but instead is held until it can be satisfied when the next normal delivery replenishes the inventory. For a firm incurring a temporary shortage in supplying its customers (as for the bicycle example), the shortage cost then can be interpreted as the loss of customers' goodwill and the subsequent reluctance to do business with the firm, the cost of delayed revenue, and the extra administrative costs. the shortage cost becomes the cost associated with delaying the completion of the production process. It is called no backlogging, if any excess of demand over available stock occurs, the firm cannot wait for the next normal delivery to meet the excess demand. Either the excess demand is met by a priority shipment, or it is not met at all because the orders are canceled. For first situation, the shortage cost can be viewed as the cost of the priority shipment. The shortage cost can also express the loss of current revenue from not meeting the demand plus the cost of losing future business because of lost goodwill. Revenue may or may not be included in the model. If both the price and the demand for the product are established by the market and so are outside the control of the company, the revenue from sales (assuming demand is met) is independent of the firm's inventory policy and may be neglected [17]**.**

The finished product system has three main components. These components include:

- Setup cost,
- Holding cost, and
- Shortages cost.

The finished product system has the form:

Total Finished Cost = Setup cost + holding cost + shortages cost

From figure 2 the following formula, the finished product total cost, is produced.

Rule 1:

$$\text{Total Finished Cost} = \frac{DC_1}{Q} + \frac{(P_1 Q - S)^2}{2P_1 Q} C_2 + \frac{S^2}{2P_1 Q} C_3 \quad \ldots \quad (1)$$

Variables explanation:

D = finished product demand per unit time,
Q = finished production quantity,
C1= set-up cost per item per cycle (or order),
C2= holding cost per item per unit time,
C3= shortages cost per unavailable unit per unit time,
S = shortages quantity,
P_1 = (1 - D / P), where P is production rate per unit time.

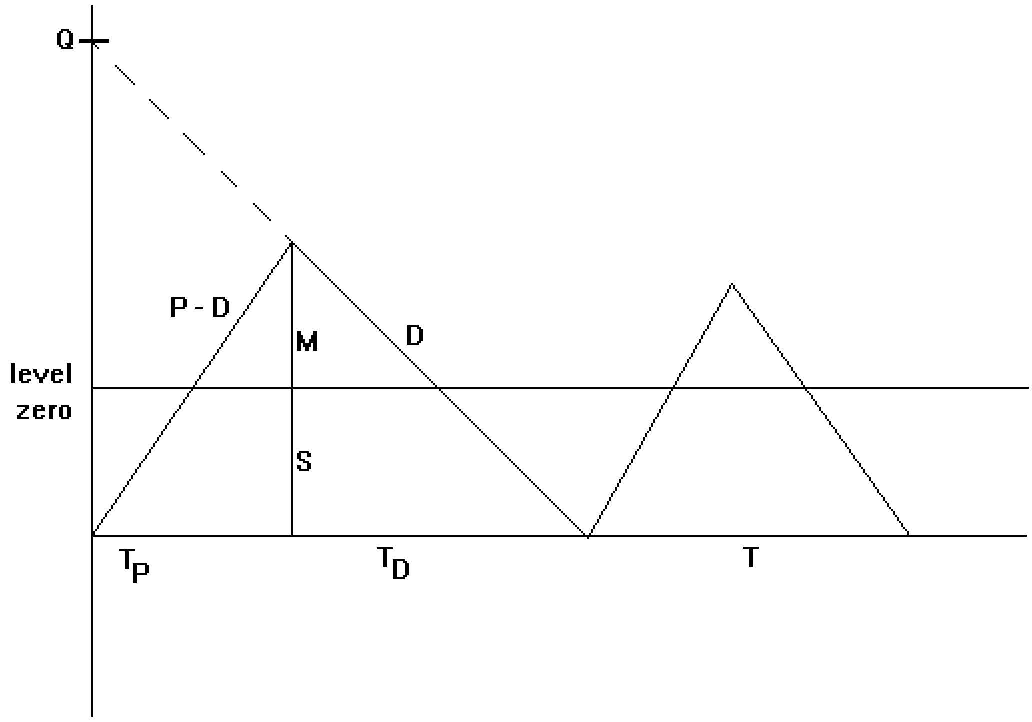

Figure 2: Finished Production Cycle

T is the length of the production cycle, T_P is the actual production time, and T_D is the demand time when there is no production processing [2].

4.2 Raw Material Model

Production processes routinely involve multi-component formulations including both manufactured defined raw materials and complex raw materials. Even minor variations in the compositions of either can lead to variability in productivity or product quality. That often persists despite the use of raw material lot blending strategy at large scales to "average out" raw material trends. And a raw material lot-blending strategy can makes it more difficult to identify which single component is responsible for a variation. Analysis of processes to identify their critical raw materials is further complicated by use of multiple raw materials that may interact with each other as well as multiple formulations that are mixed together to create a final feed medium. Identification of a raw material component causing variability in performance is a critical first step toward establishing better control over processes at manufacturing scale [18].

A finished product is produced through the process of a very complicated interaction of raw materials. Each unit of a finished product can be produced by combining, on average, hundreds of items (raw materials). The number of items from each type required is not evenly distributed. In order to facilitate the formulation and understandability of the simulated model, we assume that assembled component Aj is made up by raw materials and/or assembled components R1, R2... Rj of kind J_w out of kind w where

$J = 1, 2, 3... i_m$ and $1 <= i_m <= m$

Finished product P_i is made up by assembled components and/or raw materials $A_1, A_2, ..., A_m$ of kind i_m from kind m. This is characterized in figure 3.

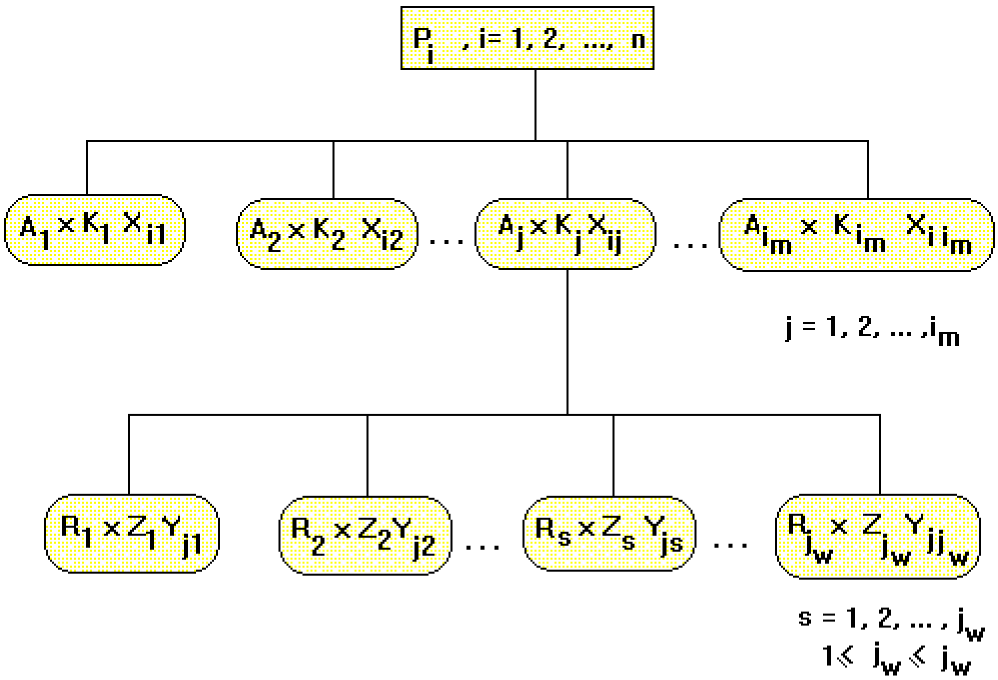

Figure 3: Characterization of raw material assemblies

The branching of the tree may continue to a finite number of levels. K_j and Z_j are decision variables indicating the time between raw material j releases for level 1 and level 2 respectively. Form figure 4, the raw material model is:

Total Raw Material Costs = Ordering Costs + Holding Costs

We assume no shortages of raw materials are permitted as situations in real life; otherwise production processing would be stopped. The model would be:

$$\text{Total Raw Material Cost} = \sum_{j=1}^{M} RMC_j(T, K_j)$$

Where **RMCj** is a function represents the cost for raw material number j. The above formula can be [4]:

Rule 2:

$$\text{Total Raw Material Cost} = \sum_{J=1}^{M} \frac{O_j}{TK_j} + \frac{1}{2}\sum_{J=1}^{M}\left[X_j\frac{DT}{P}K_j + 2b_j\right]hc_j, \qquad K_j < 1$$

Or,

Rule 3:

$$\text{Total Raw Material Cost} = \sum_{J=1}^{M} \frac{O_j}{TK_j} + \frac{1}{2}\sum_{J=1}^{M}\left[X_j\frac{DT}{P} + X_jT[K_j - 1] + 2b_j\right]hc_j, \qquad K_j >= 1$$

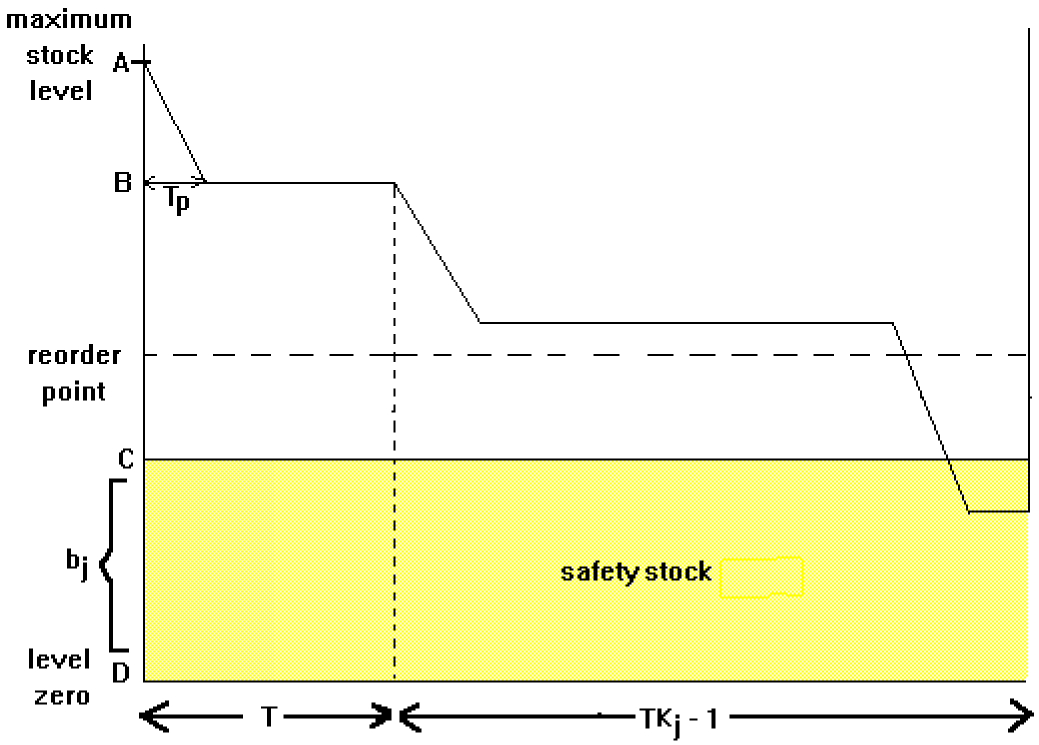

Figure 3: Raw Material Cycle Sketch

The symbols A, B, C, and D are variables used to the formulation for the raw materials costs model. K_j is a real number refers to the number of production cycles between any two consecutive replenishments of raw materials. O_j is the ordering cost for raw material j, and b_j is the safety stock for raw material j.

A number of fixed costs were not explicitly mentioned in the formulation of the model. These costs may include labor cost, machinery cost, overhead cost, ..., etc. These costs have no impact on the solution of the mathematical model. These fixed costs, can be added to the total variable costs or they can be added to any one of the following costs, i. e. the set-up costs (administration costs), holding costs, or shortages costs.

4.3 Combined Integrated System

The blueprint for success is integrated system of models. This methodology of combined integration provides a vehicle that helps arrive at the right decisions about what to schedule, what to buy, when to buy it, what to keep in stock and what to eliminate. It provides a disciplined process that effectively controls storeroom investment and associated system costs while maintaining an acceptable level of services. When finished products and raw materials models are combined, the following integrated system is produced.

Total Variable Cost = Integrated Model Cost = Finished Product Total Cost + Raw Material Total Cost

In other words,

Rule 4:

$$Tvc(T, K_j, S) = \frac{C_1}{T} + \frac{(P_1DT - S)^2}{2P_1DT}C_2 + \frac{S^2}{2P_1DT}C_3 + \sum_{J=1}^{M} RMC_j(T, K_j)$$

$$= \frac{C_1}{T} + \frac{1}{2}P_1DTC_2 - SC_2 + \frac{S^2}{2P_1DT}(C2 + C3) + \sum_{J=1}^{M}\frac{O_j}{TK_j} + \frac{1}{2}\sum_{J=1}^{M}\left[X_j\frac{DT}{P}K_j + 2b_j\right]hc_j \quad , \quad K_j < 1$$

OR,

Rule 5:

$$Tvc(T, Kj, S) = \frac{C_1}{T} + \frac{1}{2} P_1 DT C_2 - SC_2 + \frac{S^2}{2P_1 DT}(C2 + C3) + \sum_{J=1}^{M} \frac{O_j}{TK_j} + \frac{1}{2} \sum_{J=1}^{M} \left[X_j \frac{DT}{P} + X_j T(K_j - 1) + 2b_j \right] hc_j , \quad K_j >= 1 \quad ...(3)$$

Rule 4 is Rule 1 and Rule 2.
Rule 5 is Rule 1 and Rule 3.
Rule 6: if K_j is less than 1 then Trigger Rule 4.
Rule 7: if K_j is Greater or equal to 1 then Trigger Rule 5.
In order to get the optimal solution from the proposed system, a cost function of a state m is computed as follows:

$$\text{let} \quad \underline{f}^{(m)} = \begin{bmatrix} T^{(m)} \\ k_1^{(m)} \\ \vdots \\ k_n^{(m)} \\ S^{(m)} \end{bmatrix}$$

therefore,

$$\underline{f}^{(m+1)} = \underline{f}^{(m)} + \Delta \underline{f}^{(m)}$$

Transformation from one state to the next one is continued until the optimal solution is deducted.
Although analytical solutions are available to many production systems, other real life problems become complicated or impossible to analytically solve. Production systems provide mental pictures of the manufacturing processes. These mental pictures will improve manufacturing capability and flexibility, and hence reduce total cost, and increase equipment utilization [5].
Items of information about the nature of states, the cost of transforming from one state to another and the characteristics of the objectives can be used to guide the intelligent actors more efficiently. These items are expressed in the form of a heuristic evaluation function f(k, g), a function of iteration (nodes) and the objectives. This approach helps pruning fruitless paths. This is a best-first search that provides guidelines with which to estimate costs [13].
The heuristic estimation function along a path to the objective goal is:

$$f(k, g) = f_1(k, g_1) + f_2(k, g_2)$$

Where both $f_1(k, g_1)$, $f_2(k, g_2)$ are estimates of cost from the beginning to node k and from node k to last node.

V. OPTIMALITY CRITERIA

The optimum criteria methods take advantage of the knowledge on the physics and mechanics of the respective problem set. A well-known and ascertained physical law relating to structural mechanics is for instance the fully stressed design which can actually only are applied to statically determined structures. Regarding the optimum criteria methods, these criteria and the response behavior of modifications of the physical model are implemented into the algorithm. With suitable redesign rules, a convergence behavior is achieved which cannot be attained with mathematical optimizers. Applying this particular physical and mechanical knowledge, the optimum criteria methods remain limited to the certain application areas.

Applying this knowledge makes the individual optimization steps comprehensible. The optimum criteria are particularly well proven for shape and topology optimization where a large number of design variables are required. The convergence speed is independent of the number of design variables there are commercial programs to solve only simple topology optimization problem. The optimality criterion is a simple method frequently used for updating the design variables. It is a heuristic method based on the Lagrangian function. The Lagrangin multipliers are found through an iterative process [21].

The necessary and sufficient conditions for a function f(x_1, x_2, ..., x_n) to be optimal at a point $x^*=(x_1^*, x_2^*, \ldots, x_n^*)$, such that its n partial derivatives are zero, the *Hessian matrix* (the second-order partial derivatives) *principal minors* must strictly be positive for a minimum point and negative for a maximum.

In our case, the function is Tvc with three variables T*, S*, and K_j^* (J=1,2,..., M). Hessian matrix is:

$$\begin{pmatrix} \frac{\partial^2}{\partial S^2} & \frac{\partial^2}{\partial S \partial T} & \frac{\partial^2}{\partial S \partial Kj} \\ \frac{\partial^2}{\partial T \partial S} & \frac{\partial^2}{ST^2} & \frac{\partial^2}{\partial T \partial Kj} \\ \frac{\partial^2}{\partial Kj \partial S} & \frac{\partial^2}{\partial Kj \partial T} & \frac{\partial^2}{\partial Kj^2} \end{pmatrix}$$

The principal minors of the Hessian matrix are

$$\Delta_1 = \frac{\partial^2}{\partial S^2}$$

$$\Delta_2 = \begin{vmatrix} \frac{\partial^2}{\partial S^2} & \frac{\partial^2}{\partial S \partial T} \\ \frac{\partial^2}{\partial T \partial S} & \frac{\partial^2}{ST^2} \end{vmatrix}$$

$$\Delta_3 = \begin{vmatrix} \frac{\partial^2}{\partial S^2} & \frac{\partial^2}{\partial S \partial T} & \frac{\partial^2}{\partial S \partial Kj} \\ \frac{\partial^2}{\partial T \partial S} & \frac{\partial^2}{ST^2} & \frac{\partial^2}{\partial T \partial Kj} \\ \frac{\partial^2}{\partial Kj \partial S} & \frac{\partial^2}{\partial Kj \partial T} & \frac{\partial^2}{\partial Kj^2} \end{vmatrix}$$

If the conditions $\Delta_1 > 0$, $\Delta_2 > 0$, and $\Delta_3 > 0$ hold then the point (T^*, S^*, Kj^*) is a minimum. These conditions are computed using numerical differentiation of **O**(h^4) i.e. using the central-difference formula:

$$f'' = (-f_2 + 16f_1 - 30f_0 + 16f_{-1} - f_{-2})/(12h^2) + \mathbf{O}(h^4)$$

VI. CONSTRAINTS

A constraint is an element, factor, or subsystem that works as a bottleneck. It restricts an entity, project, or system (such as a manufacturing or decision making process) from achieving its potential (or higher level of output) with reference to its goal.

Constraints restrict concepts and methodology that aimed mainly at achieving most efficient flow of material in a plant through what we call a continuous process improvement. From the theory of constraints explained in [20], we assume the following:

- a manufacturing plant is an interdependent chain of links such as departments, functions, resources and some of which may have potential for greater performance but cannot realize it because of a weak link that is an external or internal constraint and every plant has at least one.
- The highest priority of a management is to maximize the plant's throughput and not just output.

Constraints are limitations preventing top management from achieving the designated goals. Constraints may be imposed on financial capabilities, space, time, and resources. In mathematical terms, constraints can be imposed on any variables from reaching the maximum, minimum, effectiveness, or perfectness objectives. For example, K_j may be constrained into $L_j <= K_j <= U_j$,

Constraints may be imposed on time (T), storage (S), or the total raw material as follows:

$$\sum_{j=1}^{i_m} X_{ij} < \text{Storage Available} \quad , \; i=1,2,\dots, m \quad 1 =< i_m =< m$$

This approach provides managers and engineers with a flexibility system that enables them to efficiently control manufacturing activities.

VII. EMPIRICAL INVESTIGATION

Empirical Investigation refers to research conducted, and conclusions reached, by means of observation, experimentation and documentation. It is a Knowledge derived from such investigation, observation, experimentation, or experience, as opposed to theoretical knowledge based on mathematical assumptions. **Empirical research** is an activity that uses empirical evidence. It is a way of gaining knowledge by means of direct and indirect observation or experience. Empirical evidence (the record of one's direct observations or experiences) can be analyzed quantitatively or qualitatively. Through quantifying the evidence or making sense of it in qualitative form, a researcher can answer empirical questions, which should be clearly defined and answerable with the evidence collected (usually called data). Research design varies by field and by the question being investigated. Many researchers combine qualitative and quantitative forms of analysis to better answer questions which cannot be studied in laboratory settings, particularly in the social sciences and in education [19]. Experiments have been conducted to demonstrate the viability of the proposed production system

Case Study 1

The method of assembling, for example, printed circuit boards is a process in which the production worker inserts components such as resistors, diodes, modules, transistors, and capacitors into an empty circuit board or raw card. The work area is in an approved electrostatic discharge area that consists of a ground work bench, chair, tools, and light box. The manufacturing process involves hundreds of activities including component placement list, pick-list, routing, part numbers, engineering change level, serial numbers, templates, and many other activities and special instructions.

To summarize things up the system asks users to provide number of production lines, number of identical items required in a circuit board, number of different items, set-up costs, raw material cost, holding costs, and others as, for example, listed below:
Input: number of items (m) = 4, set-up costs (c1) =56, manufacturing costs (c2)=2.59, shortages costs (c3) =1.9, production rate of a line (p)=380, finished product demands (d)=165, simplifying factor (p1) = 1.0-d/p, and raw material demands in a production cycle:

x[1]:= 495; x[2]:= 825; x[3]:=165; x[4]:=330;
Manufacturing costs:
hc[1]:=0.005; hc[2]:=4.221; hc[3]:=0.401; hc[4]:=10.024;
Set-up costs:
o[1]:=40.87; o[2]:=32.91; o[3]:=14.19; o[4]:=12.23;
Safety Stocks:
b[1]:= 495; b[2]:=825; b[3]:=165; b[4]:=330;

When the system is executed the minimum total cost is automatically computed and displayed as follows:

Minimum costs = $758.442
Optimal Production Cycle = 0.55 months
Shortages Allowed are: 38 units
Reorder Raw Material (1) After 78 Days
Reorder Raw Material (2) After 12 Days
Reorder Raw Material (3) After 36 Days
Reorder Raw Material (4) After 12 Days

All above information is inserted into the knowledge base so that later on queries can be issued and interrogation can be constructed.

Case Study II

Suppose that the user enters the following items of information:
Input: m= 6; c1:=34;c2:=1.59;c3:=1.2; p:=4400;d:=1155; p1:= 1.0-d/p;
Raw Material Demand:
x[1]:= 1155;x[2]:= 1155; x[3]:=2310;x[4]:=2310;x[5]:=1155;x[6]:=3465;
Holding Costs:
hc[1]:=0.05;hc[2]:=0.021;hc[3]:=0.001;hc[4]:=0.002;
hc[5]:=0.003;hc[6]:=0.01;
Ordering Costs:
o[1]:=4.87;o[2]:=2.91;o[3]:=1.19;o[4]:=3.23;o[5]:=2.74;o[6]:=4.46;
Safety Stocks:
b[1]:=10;b[2]:=20;b[3]:=10;b[4]:=10;b[5]:=10;b[6]:=10;

When the system is executed the minimum total cost is automatically computed and displayed as follows:

Minimum costs = $248.836
Optimal Production Cycle = 0.37 months
Shortages Allowed are: 182 units
Reorder Raw Material (1) After 33 Days.
Reorder Raw Material (2) After 39 Days
Reorder Raw Material (3) After 81 Days
Reorder Raw Material (4) After 96 Days
Reorder Raw Material (5) After 87 Days
Reorder Raw Material (6) After 42 Days

All above information is inserted into the knowledge base so that later on queries can be issued and interrogation can be constructed.

Case Study III

Suppose that the user enters the following items of information:
m:= 10; c1:=34;c2:=1.59;c3:=1.2; p:=4400;d:=1155; p1:= 1.0-d/p;
x[1]:= 1155;x[2]:= 1155; x[3]:=2310;x[4]:=2310;x[5]:=1155;x[6]:=3465;

x[7]:= 3465; x[8]:=4620; x[9]:= 2310; x[10]:=1155;
hc[1]:=0.05;hc[2]:=0.021;hc[3]:=0.001;hc[4]:=0.002;hc[5]:=0.003;
hc[6]:=0.01;hc[7]:=0.12; hc[8]:= 0.076; hc[9]:=0.0025; hc[10]:=0.11;
O[1]:=4.87;O[2]:=2.91;O[3]:=1.19;O[4]:=3.23;O[5]:=2.74;O[6]:=4.46;
O[7]:=4.43; O[8]:=3.21; O[9]:=8.76; O[10]:=5.01;
b[1]:=10;b[2]:=20;b[3]:=10;b[4]:=10;b[5]:=10;b[6]:=10;
b[7]:=10; b[8]:=20; b[9]:=10;b[10]:=20;

Subject to the following constraints

T > 0.0 and T <= 0.5,
S >= 0 and S <= 144,
1 <= K1 <= 1.6
1 <= K2 <= 2.3
1 <= K3 <= 3.2
1 <= K4 <= 1.9
1 <= K5 <= 1.6
1 <= K6 <= 2.6
1 <= K7 <= 1.4
1 <= K8 <= 1.6
0 <= K9 <= 2.5
1 <= K10 <= 1.6

When the system is executed the minimum total cost is automatically computed and displayed, taking into consideration the satisfaction of above 10 constraints K_i, as follows:

Minimum costs = $383.70
Optimal Production Cycle = 0.325 months
Shortages Allowed are: 134 units
Reorder Raw Material (1) After 40 Days
Reorder Raw Material (2) After 42 Days
Reorder Raw Material (3) After 42 Days
Reorder Raw Material (4) After 42 Days
Reorder Raw Material (5) After 42 Days
Reorder Raw Material (6) After 42 Days
Reorder Raw Material (7) After 39 Days
Reorder Raw Material (8) After 39 Days
Reorder Raw Material (9) After 60 Days
Reorder Raw Material (10) After 48 Days

All above information is inserted into the knowledge base so that later can be used for many purposes including issued queries. The knowledgebase can also be interrogated.

The proposed model provides insight that could be not obtained by separated modules or other methods. The system provides users with flexible mechanisms of imposing and satisfying constraints.

From case III, one can conclude that optimal production cycle length (T^*) is 0.37 months and optimal backorders (S^*) permitted is 182 units. K_j^* values are as listed above. The total variable cost is 248.836. These numbers are the optimal ones while any other combinations would increase the total variable costs.

VIII. SCIENTIFIC VALIDITY OF THE SYSTEM

Any system in real life is considered an output of the development of its initial features over time. It undergoes a process of evolution. Evolution implies the structural changes of a system to adapt to changes in technological, economical, or social environments. Monden [23] outlined that the process of a system's evolution is a cumulative development process, where both historical continuity, inherit the past element, and historical discontinuity, adaptation to new conditions; exist at the same time.

According to the above paragraph, a number of experiments have been conducted using a number of attributes such as understandability, consistency, reliability, historical development, and timesaving. Our experiments are based on evaluating two alternatives:

- The proposed intelligent integrated model
- Conventional computer-based model

The following six attributes are used to show which model achieves the best alternative.

Reliability
Querying Facilities
Consistency
Time Saving
Flexibility
Reusability.

11.1 Estimation of Attribute's Relative Weight

A relative weight estimate is adopted for judgment. The estimation is computed using the concept of importance of one attribute over the other. Typical pair-wise questions posed to different users as follows: "Do you consider Reliability more important than querying facilities? How much is more important on a scale of 1 . . 9?".

Replies from users are recorded and averages are computed. These averages are weight factors for each attribute as summarized in table1.

Table 1 Pair-wise rating of attributes

Attributes	Reliability	Querying	Consistency	Timing	Flexibility	Reusability
Reliability	1	0.1428	0.6666	4	5	3
Querying	7	1	7	6	4	3
Consistency	0.6666	0.1428	1	3	3	2
Timing	0.25	0.1666	0.3333	1	2	0.3333
Flexibility	0.2	0.25	0.3333	0.25	1	0.3333
Reusability	0.3333	0.3333	0.5	3	4	1
Col^n Sum	9.45	2.0357	9.8333	17.25	21	9.6666

For example, the following statements are equivalent:

Reliability is more important than reusability with a degree of 3. Reusability is more important than reliability with a degree of 0.3333

Whenever the relative weights in one column are different from those in another column, normalization is beneficial [8]. Normalization is achieved by dividing each entry in a column in table 1 by the corresponding column sum. Results have been summarized in table 2.

Table 2 Normalized Relative Weights

Attributes	Reliability	Querying	Consistency	Timing	Flexibility	Reusability
Reliability	0.1058	).0702	0.0678	0.2319	0.2381	0.3103
Querying	0.7407	).4912	0.7119	0.3478	0.1905	0.3103
Consistency	0.0705	).0702	0.1017	0.1739	0.1429	0.2069
Timing	0.0265	).0819	0.0339	0.0580	0.1905	0.0345
Flexibility	0.0212	).1228	0.0339	0.0145	0.0476	0.0345
Reusability	0.0353	).1637	0.0508	0.1739	0.1905	0.1034
Col^n Sum						

When row 1 (Reliability) of table 2 is summed up result will be 1.024116, row 2 is 2.79248, row 3 is 0.76608, row 4 is 0.42515, row 5 is 0.274464, and row 6 will be 0.7177. The normalized average rating associated with each attribute is summarized in table 3. For example the first entry in table 3 (0.1707) is obtained by dividing 1.024116 by 6 as there are six attributes. These averages represent the relative weights w_i.

Table 3 Averages of Relative Weights

Attributes	Reliability	Querying	Consistency	Timing	Flexibility	Reusability
Weight	0.1707	0.4654	0.1277	0.0709	0.04574	0.1196

These averages can be viewed as in figure 5.

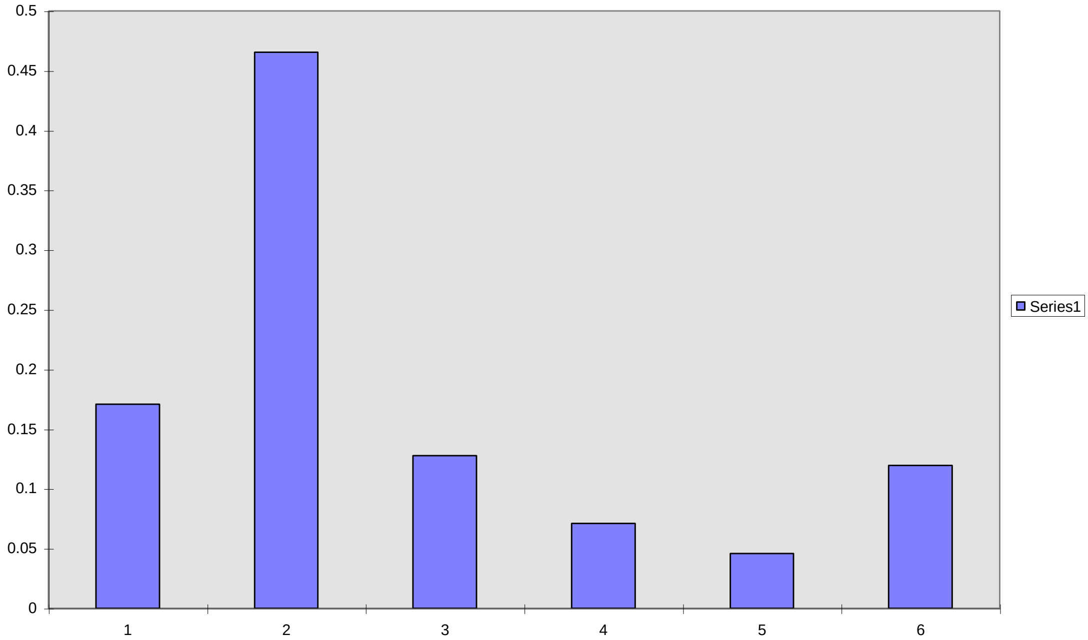

Figure 5: Bar chart for averages relative weights

11.2 Computing the Best Alternative

Similarly, we can consume relative weight for alternatives. From questionnaire, table 4 lists relative weights of the two systems with respect to each attribute:

Table 4 Alternatives Relative Weights

Attributes	Reliability	Query	Consistency	Timing	Flexibility	Reusability
alternative1	0.34	0	0.41	0.25	0.32	0
alternative2	0.66	0	0.59	0.75	0.68	0

In mathematical terms, we may describe an alternative k by writing the equation:

$$U_k = \sum_{i=1}^{p} W_i X_{ik}$$

where w1, w_2, ..., w_p are relative weights for attribute i, and x_{ik} is evaluation rating for alternative k with respect to attribute i. This is similar to models of a neuron [9] as shown in figure 5.

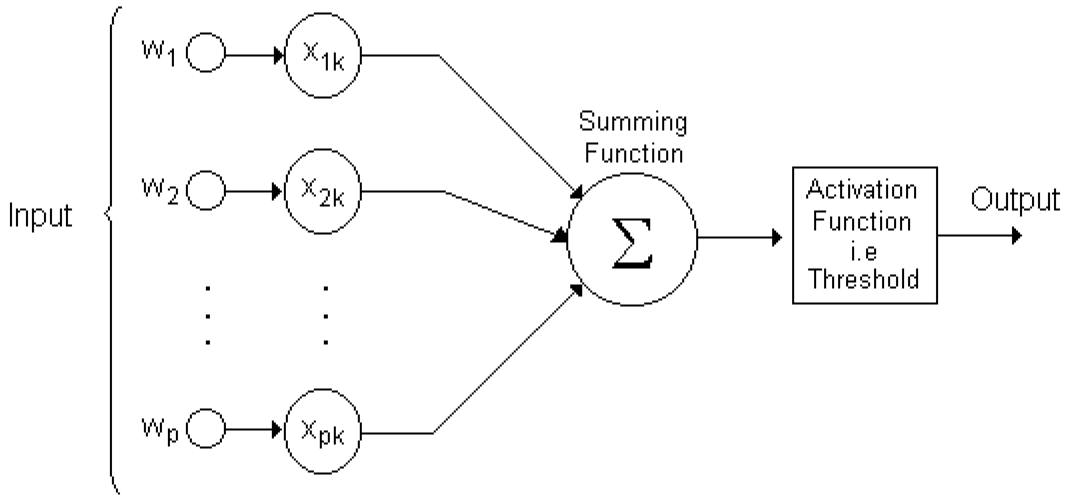

Figure 5 Alternatives evaluation

In our case, we have two systems (alternatives) and we can use the above equation to easily compute u_1 and u_2. u_1 can be computed as follows:

0.34*0.1707+0.16*0.4654+0.41*0.1277+0.25*0.0709+0.32*0.04574+0.39*0.1196 = 0.263851876,
Similarly, u_2 can be computed as follows:

0.66*0.1707+0.84*0.4654+0.59*0.1277+0.75*0.0709+0.68*0.04574+0.61*0.1196 = 0.736148120

The proposed model should be selected as it has the highest weighted rating of 0.736148120. These results are shown in figure 6.

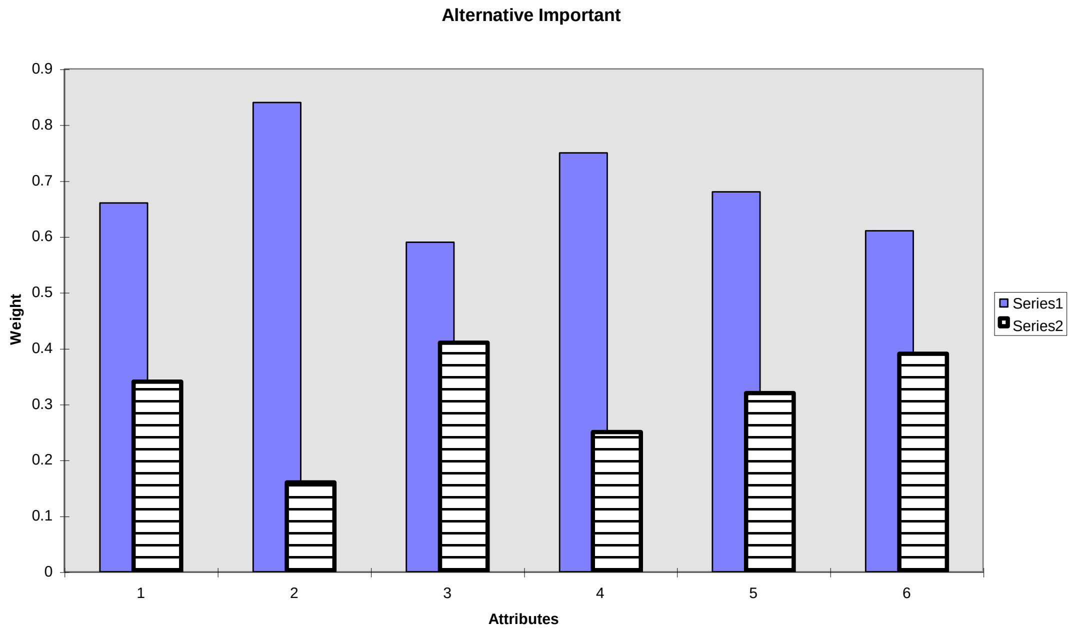

Figure 6: Bar Chart for alternatives

IX. INTERACTION WITH THE PROPOSED SYSTEM

In general, a query is a question, often required to be expressed in a formal way. In computers, what a user of a search engine or database enters is sometimes called the query. To query means to submit a question to the system and expect a reasonable answer from the system. A query can

mathematically be formulated as follows: for logic L on a domain D of structures, try to find a model in D for a given formula φ from L [22]. The concept of querying is leading beyond these 'true-false' evaluations; it introduces the result set as its outcome [23].
Think of a customer-database. One can query such a database as follows: list "All Customers in Africa" that results in a list of all customers in Africa. In case of a query like "All customers and their countries" the result consists of 2-ary tuples of a customer and a country, whereas the query "(Do) we have a customer in Rwanda" leads to either yes or no. Similarly one can define queries on structures that deliver a set of elements of the universe, where the universe relates to the data in the database [7]**.** A query is a request for information from a repository or can be formulated according to designated rules as shown in previous sections. There are three other general methods for posing queries:

- Choosing parameters from a menu: In this method, a list of parameters is presented in a system from which you can choose. This is perhaps the easiest way to pose a query because the menus guide you, but it is also the least flexible.
- Query by example (QBE): a blank record is presented by a system and lets you specify the fields and values that define the query.
- Query language: Many systems require you to make requests for information in the form of a stylized query that must be written in a special *query language*. This is the most complex and powerful method because it forces you to learn a specialized language.

Without interfacing the integrated model with intelligence mechanisms, conventional programs do not make an effective use of knowledge-based approaches used by human experts.
The proposed system enables top management to evaluate how; for example, important an item is to a company within its constraints and policies. Which item to order or to manufacture: all items, the profitable ones, production items, and/or items in demand; when to order: at safety order level, at the record level, just in time and/or according to certain constraints and rules; how much to order: stock pile, economic batch quantity, replenish, liquidate, and/or expand materials.
Top management can also issue queries and the proposed system generates the required solution efficiently. A number of attributes will be associated with each retrieved component (or group of items of information). These attributes and annotations, I believe, will provide managers with a sufficient knowledge of the retrieved component. This facility will reduce deficiencies of understandability. Many researchers claim that such facility is worth paying for because it leads to better decisions.
The proposed system provides limited facilities for natural language processing. A user can issue a query in unlimited natural language form; the system parses it and looks for specific phrases. These specific phrases are compared with stored knowledge i.e. explanations. The system chooses the sentences that have the highest number of matches. For example, if the stored explanation is of the form S1 and the issued query is in form S2 then matches can be computed as:

$$I = S1 \cap S2$$

if I is empty i.e. $I = \Phi$

then there are no matches.

The proposed system querying facilities provide customer with user-friendly interface. User-friendly means convenient approach that facilitates the interaction of a module with its environment. Interaction has different forms and meanings. For a vending machine, for example, an interaction may be the insertion of a coin. For a workstation, an interaction may be the striking of a key on a keyboard. For a procedure, an interaction may be passing parameters to the procedure. For a hardware circuit, an interaction may be the changing of voltages on certain pins.
In the case of on-line information, friendly interaction means providing users with sufficient items of information they needed with a minimum effort. To achieve such a property, the following items may be considered [10]:

- working environment,
- nature of the task i.e. structuring the functionality of the system and identifying productivity gains of the proposed system,
- adopted dialogue,

- nature of the computer-user interface itself, and
- skill needed and the appropriate training that can be measured by comfortable feeling i.e. cognitive economy.

It is not advisable assuming that human can remember cumbersome codes or rituals to complete the related work. We suggest that the environment or the user interface must provide context-sensitive help by devising an appropriate panel with suitable pull-down sequence of transactions. Grouping of items on the screen and the consistent assignment of meaning is necessary. The item should carry some sort of explanations, in other words, what is the functionality and how can be accessed.

X. CONCLUSIONS

The research addressed in this paper is concerned with building an intelligent based information system for manufacturing processing in order to support top management getting the best existing decision. It supports automatic working aids. Such automatic aids aim to record cross-referential information about product and its constituents, update, retrieve, and to keep consistent information about components of a manufacturing product whose complexity and size may require the management and control of thousands of components of differing nature (that is design, text, diagrams, components, storage locations, responsibilities, risk associated, documentation, suppliers, subcontractors,…, etc.).

Results of this research will promote the ability of manufacturing systems to act autonomously and to adapt and will enable humans to easily interact with the systems to optimize productivity. This will be accomplished through effective communication mechanisms among modules. Constraint-based representations can be considered in future work particularly for complex problems. This approach can be accomplished by describing manufacturing processing of a product as a set of constraints that the states of various stages (or components) of the production impose on the states of other components by virtue of being connected together.

For future works, we suggest that the proposed system takes into consideration the processing of demand uncertainties, high interactivity, and estimating probabilities, as published results from research along these lines are limited.

REFERENCES

[1]. Y. Shoham, (2016). Why Knowledge Representation Matters, Communications of the ACM, Vol. 59 No. 1, PP. 47-49.

[2]. K. Yu, X. Wang, and Z. Wang, (2016). An improved teaching-learning-based optimization algorithm for numerical and engineering optimization problems, Journal of Intelligent Manufacturing, August, Volume 27, Issue 4, PP. 831-843.

[3]. C. C. Bennett and K. Hauser, (2013). Artificial Intelligence Framework for Simulating Clinical Decision-Making: A Markov Decision Process Approach. Artificial Intelligence in Medicine. In Press.

[4]. S. Benjaafar, (1992). "Intelligent Simulation for Flexible Manufacturing Systems: An Integrated Approach", Computers and Industrial Engineering", Vol. 22, No. 3, PP. 297-311.

[5]. Intelligent Manufacturing Systems, (2016). Global Research and Business Innovation Program, Retrieved from http://manufacturingindaba.co.za, July 2016.

[6]. R. Davis, H. Shrobe, and P. Szolovits, (1993). What is a Knowledge Representation? *AI Magazine*, 14(1):17-33, 1993.

[7]. .G. Guida and C. Tasso, (1994). "Design and Development of Knowledge Based Systems: From Life Cycle to Methodology", John Wiley & Sons.

[8]. D. W. Patterson, (1990). "Introduction to Artificial Intelligence and Expert Systems", Prentice-Hall International, Inc.

[9]. S. M. Smyth, (2011). Intelligent Manufacturing: Real time based optimization through entire value chain, Retrieved from http://www.nist.gov/el/upload/NIST-Intelligent-Manufacturing-Susan-Smyth.pdf, June 2016.

[10]. F. Gerald and P.O. Wheatley, (1994). Applied Numerical Analysis. Fifth Edition; 1994.

[11]. S. Hahkin, (1994). Neural Networks: A Comprehensive Foundation. Macmillan College Publishing Company, Inc.

[12]. P. Sullym, (1993). Modeling the World with Objects. Prentice Hall.
[13]. J. Esparza, (2016). Automata Theory: An Algorithmic Approach, Retrieved from https://www7.in.tum.de/~esparza/autoskript.pdf, June 2016.
[14]. J. Krieger (1997). "Establishing activity-based costing: Lessons & Pitfalls". Newspaper Financial Executives Quarterly, 3(4), 14-17.
[15]. MIDCOM Data Technologies, Inc., (2016). Grocery Store Inventory Control, *Midcomdata*. Retrieved 13 June 2016.
[16]. B. A. Kildow (2011). Supply Chain Management Guide to Business Continuity, American Management Association.
[17]. D. Blanchard, (2010). Supply Chain Management Best Practices, 2nd. Edition, John Wiley & Sons.
[18]. S. Kalpakjian and S.R. Schmid, (2008). Manufacturing process for engineering materials (5th ed.), solutions manual, Pearson Education, Inc., Upper Saddle River, NJ.
[19]. C. J. Goodwin, (2005). Research in Psychology: Methods and Design, USA: John Wiley & Sons, Inc.
[20]. Theory of constraints (2016), Retrieved from website: http://www.businessdictionary.com/definition/theory-of-constraints, June, 2016.
[21]. A. Shukla, A. Misra, (2013). Review of Optimality Criteria Approach Scope, Limitation and Development in Topology Optimization, International Journal of Advances in Engineering & Technology, Sept. 2013, Vol. 6, Issue 4, pp. 1886-1889.
[22]. H. Bakhshi, G. Kapetanios, and A. Yates, (2005). "Rational Expectations and Fixed Events Forecasts: An Application to UK Inflation," Empirical Economics, 30, PP. 539-553.
[23]. Y. Monden. (2012), Toyota Production System: An Integrated Approach to Just-In-Time, 4th edition, Taylor & Francis Group, LLC.

AUTHORS BIOGRAPHY

Abid Thyab Al Ajeeli was born in Tikrit, Iraq. He received the Bachelor degree in computer Science from the University of London, in 1977 and the Master degree in Operational Research from the University of Southampton, in 1978. He received the Ph.D. degree in Software Engineering from the University of Keele, U.K., in 1991. His research interests include Software Engineering, Expert Systems, Arabization, and Industrial Manufacturing Automation.