ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 4, April 2019

To measure impacts of Agent Technology in manufacturing control system and prioritization by Fuzzy AHP

Sunil Kumar*, Dharmendra Kumar, Amit Gangwar

Assistant Professor MED, Dr. M.C. Saxena college of Engineering and Technology, Lucknow - INDIA
Assistant Professor MED, Dr. M.C. Saxena college of Engineering and Technology, Lucknow – INDIA
Assistant Professor MED, Dr. M.C. Saxena college of Engineering and Technology, Lucknow - INDIA

ABSTRACT: In flexible manufacturing system, the account of the control policy should modernize in routine for this purpose, new methods need to deploy to account for fluctuations in control of production system and agent technology can serve this function. Agent technology recognized as formidable tool for modern manufacturing system. Many researchers are working for implementations of agent technology in manufacturing industries, production planning and scheduling, process control, designing, diagnosis, marketing, optimization etc. This article presents the application of agent technology for manufacturing control in modern manufacturing system. The research used the secondary data and based on literature review, we purposed the hypothesis. Seven variables has been identified which contribute to process control in manufacturing system, their contribution is discussed and their relative priority is calculated by fuzzy analytic hierarchy process (FAHP).

KEYWORDS*:* Agent technology; Process control; Fuzzy analytic hierarchy process.

I. INTRODUCTION

The manufacturing sector has reached a time where computer technology has focused from hardware components to software components. The requirement for unceasing real-time information flow pushes information technology developers to create control system models, and software to support this flow. In present time, the market has become more demanding for lower cost, enhanced quality and speedy time to market hence forcing the industries to be more agile for their job. The effective and efficient utilization of external and internal resources is required for agility to act quickly as per customer requirement. Agile manufacturing works for minimizing manufacturing costs, expanding market share, satisfying the customers, introducing new products rapidly, lowering down the non-value addition time, and to be competitive to rival manufacturing company. And to back the users in managing different tasks in manufacturing organization through a set of small, distributed, independent, configurable, smart, and interactive systems designed to fulfill their specific objectives while globally attaining highest performance of the overall manufacturing enterprise's production and commercial system. Agent technology appears to fulfill this requirement [1].

The notion of 'agent' comes from vocabulary of distributed artificial intelligence (DAI) popular in the 1970s. Exploration on agents and multi-agent systems (MASs) has then grown and touching many applications, in different fields' defense, healthcare, manufacturing and business services. Agents are widely used in production, system integration, modeling, simulation, assembling, control, robotics, planning, maintenance, digital enterprises development etc. [2]. Many researches have given the definitions of agents, but following description is found to much suitable, ' An agent is an encapsulated computer system that is placed in some atmosphere, and that is accomplished of flexible, independent action in that environment in order to fulfill its design purposes' [3]. Generally number of agents works in system called as multi agent system (MAS). An agent is system which have a.) Autonomy: self-governing property because an agent have the capability to execute most of its responsibilities without the straight involvement of humans and it have a degree of governing its own activities and internal state[3]. b.) Reactivity: they can perceive the environment and can act accordingly. c.) Proactiveness: agents don't just act in reaction to their environment, they are capable to show goal oriented behavior by compelling the initiative. d.) Social ability: an agent communicate with another agent (possibly human also) by particular kind of communication language and it have capability to involve in social activity to achieve the goal. e.) Mobility: agents should have capability to adjust its physical position to expand its problem resolving ability.

ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

Vol. 6, Issue 4, April 2019

This paper utilizes fuzzy analytic hierarchy process (FAHP) to compute the relative weight of identified variables. This article organized as: In second section, we present the conceptual background and hypothesis. In section three, we have described the methodology used in the study. Numeric application of proposed model are described in section four and finally the set conclusions drawn from the study are listed in section five.

II. CONCEPTUAL MODEL AND HYPOTHESIS

Manufacturing systems entails tasks linked to the manufacturing of products by consuming manufacturing resources and information, according to the demand of product. A manufacturing system is of hardly any benefit, without the presence of a proper control system and, the flexibility of manufacturing system depends not only just on its machineries (e.g. machine tool, work handling system etc.) but also depends on the corresponding control system. Ref. [4] discusses four kinds of control architecture: 1. Centralized, 2. Hierarchical, 3. Modified hierarchical and 4. Heterarchical. The manufacturing control system deals with the handling and monitoring the various activities/tasks in production, as per the production plan, and to check the progress in processing of product, assembly operation, and inspection/quality check. At this level it is decided that what to manufacture, in what way to manufacture, when production is to completed and how and when to use the resources, when to release the job into factory, which job to release, job routing, and job sequencing [5]. By going through the literature, we have identified six variables; where agents have noteworthy and affirmative influence on manufacturing control system.

Process planning agent (PP) decides the order of different manufacturing tasks required to manufacture a product [6]. The real-time process planning eases the selection of the optimized route option, resource substitutes, and detail process planning [7]. Scheduling agent (SA) deals with comprehensive plan of the project work/tasks with respect to time. The scheduling involves with the allotment of tasks to resources, within a shorter time-based prospect and regarding to specific creation e.g. the due date priority [5]. Scheduling agent assign tasks to minimal resource in such a way so that more purpose are optimized [8]. Decision support tool (DST) is a computer centered information system, which helps in the managing the operations, and planning stages of a manufacturing system and provides assistances in decisions making. Computer programs utilize artificial intelligence technique for study and automation of some tasks [9]. In the complex and evaluative atmosphere, manufacturers must knowledge have of the processes before using them in order to get success in the first attempt. To complete this objective, virtual manufacturing (VM) is used. VM environment [10] will facilitate a computationally created environment to simulate separate manufacturing operations. VM models does simulation and optimization of the critical processes. Global manufacturing (GM) evolves a manufacturing supply chain system comprising of suppliers, industrial unit, sub-contractors, warehouses, delivery centers and vendors, via which raw materials are acquired, transformed, manufactured and delivered to the customers [11]. Such a supply chain is comparatively complex as compare to that for ordering, production and delivery of a simple product, for not only the volume and difficulty of dealings, but also because of its dynamic and diverse manufacturing environments. A manufacturing system consists of number of machines (various material removal tool, assembly & quality control tools etc.). A machine agent (MA) needs to be loaded to its potential, but not to exhaust its resources [12]. Organization, Machine model, Energy consumption are some of the attributes of machine agent. Networking between agents (NBA) is mutual interaction between agents [13]. The information framework is discussed in TABLE I

TABLE I . .Information framework for the study

Variables	Focus	References
1. Process planning	It utilizes the resource allocation of activities of employees, materials and production capacity, in order to serve different customers.	[6], [7]
2. Scheduling agent	Deals with comprehensive plan of the project work/tasks with respect to time.	[5], [8]
3. Decision support tool	Computer centered information system, which helps in the managing the operations and planning stages of a manufacturing system and provides assistances in decisions making.	[9]
4. Virtual manufacturing	VM models does simulation and optimization of the critical processes.	[10]
5. Global manufacturing	Production and selling takes place in many countries.	[11]

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 4, April 2019

6.	Machine agent	Needs to be loaded to its potential, but not to exhaust its resources	[12]
7.	Networking between agents	Mutual interaction between various agents in manufacturing system.	[13]

The study had considered whether agent technology increases the control within system and the findings suggest that agent technology can contribute positively in manufacturing control.
The purposed hypothesis is:
Hypothesis: Agent technology has a noteworthy and affirmative influence on manufacturing control

III. METHODOLOGY

A. FUZZY AHP

This paper drives the use of FAHP approach to find the relative weightage of the identified variables' for manufacturing control system. FAHP is enhancement of analytic hierarchy process (AHP), multi measures decision-making procedure that is widely used for getting solution of imprecise hierarchical problems. Ref [14] purposes AHP, which is potent and usually used tool for multi criteria decision-making problem. Ref. [15] introduced the straight application of triangular fuzzy number (TFN) for pairwise judgment matrix of AHP. However, AHP method has certain shortcomings in dealing with vagueness for ranking, so AHP cannot be used in complex and uncertain problems. In AHP human priorities is represented by crisp values but in several real problems the human priority model is ambiguous and person responsible for decision making may feel unenthusiastic to allocate crisp values to the results, thus it proves unproductive in managing vagueness in the problems. Contrary, fuzzy set theory has proven to provide better results for the models having ambiguity and vagueness. Fuzzy set theory comprises several terms such as fuzzy data investigation, fuzzy logic and fuzzy mathematical programming. FAHP is a synthetic extent investigation method that utilizes triangular fuzzy numbers to choose the importance between two judgment variables. The extent investigation technique uses computation of the importance of the pairwise comparison [16]. Thus utilizing TFN, in extent investigation technique the final priority/importance weights of choices is calculated. The choice with maximum weight would get the maximum importance.

B. TRIANGULAR FUZZY NUMBER

A fuzzy set described by its characteristic function (CF). CF can have a limited value from zero to one in a fuzzy set. In fuzzy set, general linguistic/verbal relationships like "large", "medium", and "small" used to adjust the range of numeric values. A fuzzy number in a fuzzy set is denoted as $A = \{(x, \mu_A(x)), x \in R\}$, where $\mu_A(x)$ symbolizes the characteristic value linked through x. If a fuzzy number belongs to a triangular characteristic function, it will be denoted as shown in Fig. 1

$$\mu_A(x) = 0, for\ x \in (-\infty, l]$$
$$\mu_A(x) = 1, at\ x = m$$
$$\mu_A(x) = 0, for\ x \in [n, -\infty)$$

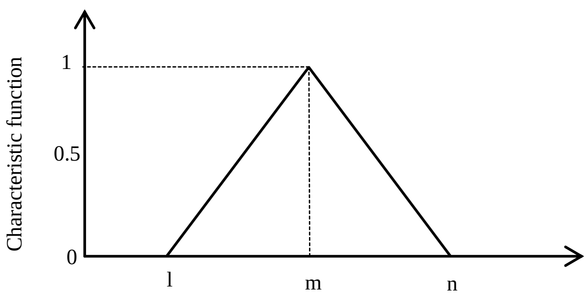

Figure 1. Triangular fuzzy number

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 4, April 2019

Where 'l', 'm', and 'n' denotes the minimum possible value, the most favorable value and the largest possible value respectively.

Linguistic scales for importance [17]
Triangular fuzzy numbers which are 'equally important' (EI), 'weakly more important' (WMI), 'strongly more important' (SMI), 'very strongly more important' (VSMI), and 'absolutely more important' (AMI) signify the pairwise comparison of decision variables from a linguistic range of EI to AMI. Ref. [17] gave a scale for pairwise comparison of decision variables as shown in TABLE II. It discusses a triangular fuzzy scale conforming to linguistic scale for making comparison matrices.

TABLE II . LINGUISTIC SCALE FOR IMPORTANCE/PRIORITY

Linguistic variable	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1,1,1)	(1,1,1)
EI	(1/2,1,3/2)	(2/3,1,2)
WMI	(1,3/2,2)	(1/2,2/3,1)
SMI	(3/2,2,5/2)	(2/5,1/2,2/3)
VSMI	(2,5/2,3)	(1/3,2/5,1/2)
AMI	(5/2,3,7/2)	(2/7,1/3,2/5)

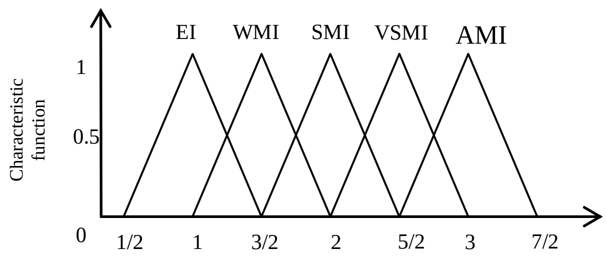

Figure 2. Linguistic scale for relative impotance. [18]

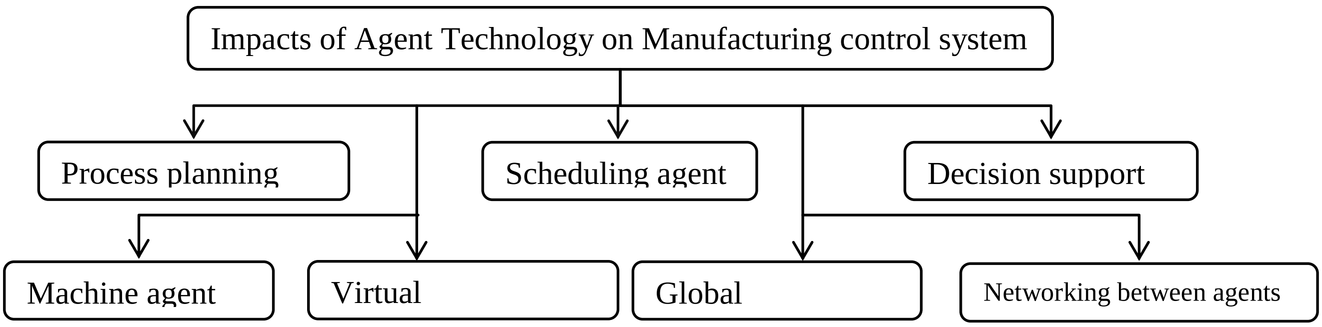

Figure 3. Hierarchical model for Fuzzy AHP approach

ISSN: 2350-0328

International Journal of AdvancedResearch in Science, Engineering and Technology

Vol. 6, Issue 4, April 2019

TABLE III . COMPARISON MATRIX FOR INDENTIFIED VARIABLES

	PP	SA	DST	MA	VM	GM	NBA	Weight
PP	(1,1,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1,3/2,2)	(3/2,2,5/2)	(1,3/2,2)	**0.147**
SA	(1,3/2,2)	(1,1,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	**0.172**
DST	(1,3/2,2)	(1,3/2,2)	(1,1,1)	(1/2,1,3/2)	(1/2,2/3,1)	(1,3/2,2)	(1,3/2,2)	**0.144**
MA	(1,3/2,2)	(1,3/2,2)	(2/3,1,2)	(1,1,1)	(1,3/2,2)	(3/2,2,5/2)	(1,3/2,2)	**0.188**
VM	(1/2,2/3,1)	(1,3/2,2)	(1,3/2,2)	(1/2,2/3,1)	(1,1,1)	(1,3/2,2)	(1/2,2/3,1)	**0.135**
GM	(2/5,1/2,2/3)	(1,3/2,2)	(1/2,2/3,1)	(2/5,1/2,2/3)	(1/2,2/3,1)	(1,1,1)	(2/5,1/2,2/3)	**0.072**
NBA	(1/2,2/3,1)	(1,3/2,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1,3/2,2)	(3/2,2,5/2)	(1,1,1)	**0.142**
								1.000

Various steps involved in developing FAHP model are discussed below.

Step 1: Categorize the variables and sub variables identified in the model.

Step 2: Make a hierarchical decomposition of variables, sub variables categorized in first step.

Step 3: Formulate the 'pairwise comparison matrices' using linguistic/verbal scale for each variable and sub variable at all levels separately.

Step 4: Calculate 'fuzzy synthetic extent value' by Chang's extent investigation technique [16].

Step 5: Find degree of possibility for all the calculated fuzzy extent values.

Step 6: Identified the least of degree of possibility for all alternatives that characterizes the weight/priority vector of specific matrix.

Step 7: Finally, normalize the calculated weight vector.

IV. NUMERIC APPLICATION OF PROPOSED MODEL

In the purposed model, seven variables are identified to be priorities based on their contribution to manufacturing control system as shown in Fig. 3.

Step-1: Let $M_{c_i}^{j}$ is extent analysis of the i[th] attribute, for i = (1, 2, 3,……., n). Now the fuzzy synthetic extent (SNE) w.r.t. the i^{th} measures is defined as:

$$SNE_i = \sum_{j=1}^{m} M_{c_i}^{j} \times [\sum_{i=1}^{n} \prod_{j=1}^{m} M_{c_i}^{j}]^{-1}$$

Where all $M_{c_i}^{j}$(j= 1,2,3…….,m) are the triangular fuzzy numbers.

$$\sum_{j=1}^{m} M_{c_i}^{j} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} n_j), \ [\sum_{i=1}^{n} \prod_{j=1}^{m} M_{c_i}^{j}]^{-1} = (\frac{1}{\sum_{i=1}^{n} n_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i})$$

The values of fuzzy synthetic extent calculated as:

$$SNE_1 = (5.00, 6.50, 8.50) \times \left({}^{1}/_{60.33}, {}^{1}/_{45.17}, {}^{1}/_{32.63}\right) = (0.083, 0.144, 0.260)$$

$$SNE_2 = (5.50, 7.67, 10.0,) \times \left({}^{1}/_{60.33}, {}^{1}/_{45.17}, {}^{1}/_{32.63}\right) = (0.091, 0.170, 0.306)$$

$$SNE_3 = (4.50, 6.33, 8.50) \times \left({}^{1}/_{60.33}, {}^{1}/_{45.17}, {}^{1}/_{32.63}\right) = (0.075, 0.140, 0.260)$$

$$SNE_4 = (6.17, 8.50, 11.50) \times \left({}^{1}/_{60.33}, {}^{1}/_{45.17}, {}^{1}/_{32.63}\right) = (0.102, 0.188, 0.352)$$

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 4, April 2019

$$SNE_5 = (4.50, 6.00, 8.00) \times \left({}^{1}/_{60.33}, {}^{1}/_{45.17}, {}^{1}/_{32.63} \right) = (0.075, 0.133, 0.245)$$

$$SNE_6 = (3.30, 6.17, 8.50) \times \left({}^{1}/_{60.33}, {}^{1}/_{45.17}, {}^{1}/_{32.63} \right) = (0.055, 0.089, 0.163)$$

$$SNE_7 = (3.67, 6.17, 8.50) \times \left({}^{1}/_{60.33}, {}^{1}/_{45.17}, {}^{1}/_{32.63} \right) = (0.061, 0.137, 0.260)$$

Step 2: Calculation for degree of possibility:
The degree of possibility of $SNE_1 = (l_1, m_1, n_1) \geq SNE_2 = (l_2, m_2, n_2)$ is defined as:

$$V(SNE_1 \geq SNE_2) = \begin{cases} 1, & if\ m_2 > m_1 \\ 0, & if\ l_1 \geq l_2 \\ \frac{(l_2 - n_1)}{(m_1 - n_1) - (m_2 - l_2)}, & otherwise \end{cases}$$

$V(SNE_1 \geq SNE_2)=0.868$, $V(SNE_1 \geq SNE_3) = 1$, $V(SNE_1 \geq SNE_4) = 0.781$, $V(SNE_1 \geq SNE_5) = 1$, $V(SNE_1 \geq SNE_5) = 1$, $V(SNE_1 \geq SNE_7) = 1$

$V(SNE_2 \geq SNE_1) = 1$, $V(SNE_2 \geq SNE_3) = 1$, $V(SNE_2 \geq SNE_4) = 0.917$, $V(SNE_2 \geq SNE_5) = 1$, $V(SNE_2 \geq SNE_6) = 1$, $V(SNE_2 \geq SNE_7) = 1$
$V(SNE_3 \geq SNE_1) = 0.980$, $V(SNE_3 \geq SNE_2) = 0.852$, $V(SNE_3 \geq SNE_4) = 0.767$, $V(SNE_3 \geq SNE_5) = 1$, $V(SNE_3 \geq SNE_6) = 1$, $V(SNE_3 \geq SNE_7) = 1$

$V(SNE_4 \geq SNE_1) = 1$, $V(SNE_4 \geq SNE_2) = 1$, $V(SNE_4 \geq SSNE_3) = 1$, $V(SNE_4 \geq SNE_5) = 1$, $V(SNE_4 \geq SNE_6) = 1$, $V(SNE_4 \geq SNE_7) = 1$

$V(SNE_5 \geq SNE_1) = 0.936$, $V(SNE_5 \geq SNE_2) = 0.807$, $V(SNE_5 \geq SNE_3) = 0.959$, $V(SNE_5 \geq SNE_4) = 0.721$, $V(SNE_5 \geq SNE_6) = 1$, $V(SNE_5 \geq SNE_7) = 0.980$

$V(SNE_6 \geq SNE_1) = 0.593$, $V(SNE_6 \geq SNE_2) = 0.471$, $V(SNE_6 \geq SNE_3) = 0.632$, $V(SNE_6 \geq SNE_4) = 0.381$, $V(SNE_6 \geq SNE_5) = 0.667$, $V(SNE_6 \geq SNE_7) = 0.682$

$V(SNE_7 \geq SNE_1) = 0.960$, $V(SNE_7 \geq SNE_2) = 0.836$, $V(SNE_7 \geq SNE_3) = 0.981$, $V(SNE_7 \geq SNE_4) = 0.754$, $V(SNE_7 \geq SNE_5) =1$, $V(SNE_7 \geq SNE_6) = 1$

Step 3: The minimum degree possibility:
$V (SNE \geq SNE_1, SNE_2,\ldots\ldots SNE_k) = \min V (SNE \geq SNE_i)$, $i = 1, 2\ldots\ldots,k$.
$\min V (SNE_1 \geq SNE_2, SNE_3, SNE_4, SNE_5, SNE_6, SNE_7) = 0.781$
$\min V (SNE_2 \geq SNE_1, SNE_3, SNE_4, SNE_5, SNE_6, SNE_7) = 0.917$
$\min V (SNE_3 \geq SNE_1, SNE_2, SNE_4, SNE_5, SNE_6, SNE_7) = 0.767$
$\min V (SNE_4 \geq SNE_1, SNE_2, SNE_3, SNE_5, SNE_6, SNE_7) = 1$
$\min V (SNE_5 \geq SNE_1, SNE_2, SNE_3, SNE_4, SNE_6, SNE_7) = 0.721$
$\min V (SNE_6 \geq SNE_1, SNE_2, SNE_3, SNE_4, SNE_5, SNE_7) = 0.381$
$\min V (SNE_7 \geq SNE_1, SNE_2, SNE_3, SNE_4, SNE_5, SNE_6) = 0.754$

Step 4: The weight vector is calculated by:
$W_p = (\min V (SNE_1 \geq SNE_i), \min V (SNE_2 \geq SNE_i),\ldots\ldots \min V (SNE_k \geq SNE_i))^T$
$W_P = (0.781, 0.917, 0.767, 1, 0.721, 0.381, 0.754)^T$

Step 5: Lastly, normalize the obtained weight vectors. And the required normalized weight vector is:
$W_0 = (0.147, 0.172, 0.144, 0.188, 0.135, 0.072, 0.142)^T$

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 4, April 2019

The calculated weights shown below in Fig. 4.

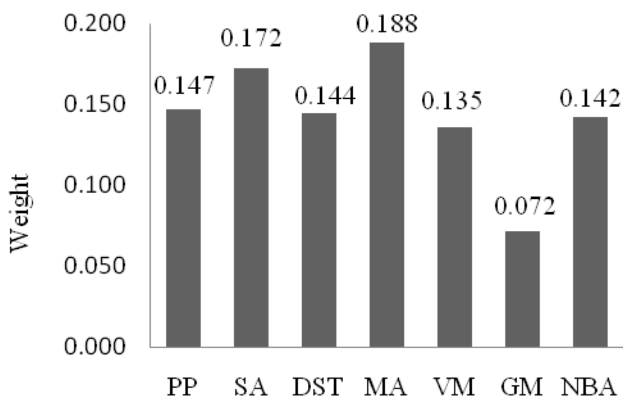

Figure 4. Weight of respective variable as calaculted.

V. CONCLUSION

This study proposed the model for prioritizing the variable in manufacturing control, where agents can be used. We have identified seven variables (i.e. process planning, scheduling agent, decision support tool, machine agent, virtual manufacturing, global manufacturing, and networking between agents) and discussed their contribution in manufacturing control. Fuzzy AHP used to measure the relative importance of respective variable to manufacturing control. The relative weight of machine agent (weight 0.188) is highest among the identified variables, which implies that contribution of agents in machine control is very important. After machine agents, scheduling agent (weight 0.172) and process planning agent (weight 0.147) comes. We found out that contribution of agent in minimum for global manufacturing among the identified variables, so there need for research in this area. The study would help in deciding the importance of agents in manufacturing control, and to make the control system of manufacturing better.

REFERENCES

[1] *Agent-Based Manufacturing and Control Systems*. Taylor & Francis, 2005.
[2] M. Adeyeri, K. Mpofu and O. Adenuga, "Integration of agent technology into manufacturing enterprise: A review and platform for industry 4.0", *2015 International Conference on Industrial Engineering and Operations Management (IEOM)*, 2015.
[3] M. Wooldridge, "Agent-based software engineering", *IEE Proceedings - Software Engineering*, vol. 144, no. 1, p. 26, 1997.
[4] D. Dilts, N. Boyd and H. Whorms, "The evolution of control architectures for automated manufacturing systems", *Journal of Manufacturing Systems*, vol. 10, no. 1, pp. 79-93, 1991.
[5] P. Leitão, "Agent-based distributed manufacturing control: A state-of-the-art survey", *Engineering Applications of Artificial Intelligence*, vol. 22, no. 7, pp. 979-991, 2009.
[6] S. Feng, K. Stouffer and K. Jurrens, "Manufacturing planning and predictive process model integration using software agents", *Advanced Engineering Informatics*, vol. 19, no. 2, pp. 135-142, 2005.
[7] Weiming Shen, Lihui Wang and Qi Hao, "Agent-based distributed manufacturing process planning and scheduling: a state-of-the-art survey", *IEEE Transactions on Systems, Man and Cybernetics, Part C (Applications and Reviews)*, vol. 36, no. 4, pp. 563-577, 2006.
[8] P. Cowling, D. Ouelhadj and S. Petrovic, "A multi-agent architecture for dynamic scheduling of steel hot rolling", *Journal of Intelligent Manufacturing*, vol. 14, no. 5, pp. 457-470, 2003.
[9] R. Kothamasu, S. Huang and W. VerDuin, "System Health Monitoring and Prognostics – A Review of Current Paradigms and Practices", *Handbook of Maintenance Management and Engineering*, pp. 337-362, 2009.
[10] Z. Xu, Z. Zhao and R. Baines, "Constructing virtual environments for manufacturing simulation", *International Journal of Production Research*, vol. 38, no. 17, pp. 4171-4191, 2000.
[11] J. (Roger) Jiao, X. You and A. Kumar, "An agent-based framework for collaborative negotiation in the global manufacturing supply chain network", *Robotics and Computer-Integrated Manufacturing*, vol. 22, no. 3, pp. 239-255, 2006.
[12] V. Shpilevoy, A. Shishov, P. Skobelev, E. Kolbova, D. Kazanskaia, Y. Shepilov and A. Tsarev, "Multi-agent system "Smart Factory" for real-time workshop management in aircraft jet engines production", *IFAC Proceedings Volumes*, vol. 46, no. 7, pp. 204-209, 2013.
[13] T. Ottaway and J. Burns, "An adaptive production control system utilizing agent technology", *International Journal of Production Research*, vol. 38, no. 4, pp. 721-737, 2000.
[14] Y. Wind and T. Saaty, "Marketing Applications of the Analytic Hierarchy Process", *Management Science*, vol. 26, no. 7, pp. 641-658, 1980.

ISSN: 2350-0328
International Journal of AdvancedResearch in Science, Engineering and Technology
Vol. 6, Issue 4, April 2019

[15] P. van Laarhoven and W. Pedrycz, "A fuzzy extension of Saaty's priority theory", *Fuzzy Sets and Systems*, vol. 11, no. 1-3, pp. 229-241, 1983.
[16] D. Chang, "Applications of the extent analysis method on fuzzy AHP", *European Journal of Operational Research*, vol. 95, no. 3, pp. 649-655, 1996.