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An Approach to Assess Uncertainties in Cloud Manufacturing

Yaser Yadekar, Essam Shehab[1] and Jorn Mehnen
Manufacturing Department, Cranfield University, UK

Abstract. As new technologies and advanced networks play an increasing important role in manufacturing, many enterprises are suffering from unknown and unpredictable situations, termed "uncertainties". The aim of this paper is to provide an approach to evaluate the importance of uncertainties in Cloud Manufacturing. The Simple Multi-Attribute Rating Technique (SMART) was used in this research to assess uncertainties that exist in Cloud Manufacturing. Additionally, a Microsoft Excel assessment tool has been developed to help decision makers identify uncertainties and determine the weight of uncertainty in Cloud Manufacturing.

Keywords. Cloud Manufacturing, Uncertainties, Simple Multi-Attribute Rating Technique (SMART)

Introduction

Technology plays an ever more important role in linking enterprises and markets. The development of new technologies has helped enterprises to support their decision-making processes; to gain competitive advantage; and to enter new markets globally. New technologies such as Cloud Computing, Internet of Things, Virtualization, and Web Services, with the support of existing advanced manufacturing networks has the ability to change and restructure manufacturing systems in the manufacturing industry [1]. However, the manufacturing industry is facing many problems with existing manufacturing networks that affect the whole life cycle of the manufacturing process. Those problems include: manufacturing resources sharing, accessibility of equipment, and knowledge sharing [1,2,3,4].

With the emergence of new technologies, a new manufacturing paradigm, called "Cloud Manufacturing", has arisen and received attention from both researchers and professionals over the past few years [5]. This paradigm allows: sharing of manufacturing resources, capabilities, and knowledge between different parties (manufacturing units, suppliers, other enterprises and customers) [6]; reduction in costs, and maximization of productivity, business agility and innovation [7].

Appling new and complex technologies and networks in enterprises can create unknown and unpredictable situations, known as "uncertainties". Every enterprise tries to avoid, at any cost, having the undesirable state of 'uncertainty' in their system, as more uncertainty in a problem can lead to less understanding of that problem [8].

[1] Corresponding author; E-mail: e.shehab @cranfield.ac.uk

The remainder of this paper is structured as follows: Section 2 provides a brief description of the Cloud Manufacturing concept; Section 3 explains the proposed methodology in this paper; Section 4 presents an overview of uncertainty assessment for Cloud Manufacturing; Section 5 demonstrates the development of an assessment tool; Finally, Section 6 concludes the paper and discusses future work.

1. Cloud Manufacturing Concept

Cloud Manufacturing is a new paradigm which has resulted from changes in global market demands, the invention of new technologies, and developments in advanced communication networks [9]. This new paradigm offers, for the whole life cycle of manufacturing, faster, safer, more reliable, high-quality, cheap and on-demand manufacturing services [10]. Figure (1) shows traditional manufacturing and Cloud Manufacturing.

In traditional manufacturing, the customer's drawing is transferred into CAD and CAM systems to generate G-Code for a machine to manufacture the part. This can be done by using manual or mechanised transformational techniques. However, in Cloud Manufacturing, manufacturing resources and manufacturing capabilities needed for the whole lifecycle of a product are transferred into the Cloud. This can be done by using intelligent and automatic techniques.

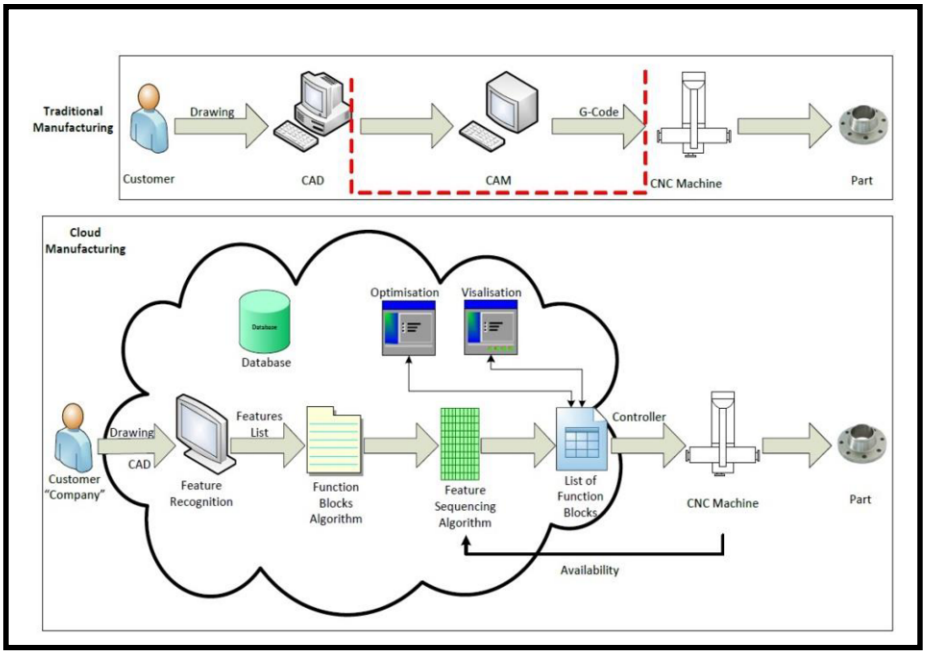

Figure1. Traditional manufacturing and Cloud Manufacturing.

2. Research Methodology

Initially, a combination of a literature review (Journal papers, reports and documents), interviews, a questionnaire, a Delphi survey, and workshops with experts was used in this research in order to identify uncertainties and to determine the most important dimensions in Cloud Manufacturing [11,12]. From this, a total of 32 potential uncertainty factors were identified, with four important dimensions: Security, Performance, Cost and Regulatory).

Subsequently, the Simple Multi-Attribute Rating Technique (SMART) was identified from the literature as a suitable approach to assess the importance (weight) of uncertainty in Cloud Manufacturing. This technique is one of several weighting methods based on elicitation in a multiple-criteria decision analysis (MCDM) approach that uses experts' or stakeholders' judgment to weight the importance of multiple categories and their alternatives.

3. Uncertainty Assessment

After identifying potential uncertainties, there is a need to evaluate each uncertainty. This evaluation delivers a rating for the various uncertainties that is then used to determine strategies and decisions on how to deal with uncertainty in a Cloud Manufacturing. The process of uncertainty assessment is conducted in three essential phases: identify all potential uncertainties in the Cloud Manufacturing; estimate the importance of uncertainty (weight); rate uncertainties according to value of weight for each uncertainty in the system.

Multiple-criteria decision analysis (MCDA) is a technique in the operations research discipline that has ability to handle and solve issues involving: multiple factors; a large amount of information and knowledge; and different alternatives [13].

There are different weighting methods based on elicitation in a MCDM approach that uses experts' or stakeholders' judgment to weight the importance of categories and alternatives [14]. Some of weighting techniques include: Simple Multi-Attribute Rating Technique (SMART), that implements direct entry of relative scores and weights for criteria and alternatives weighting; Swing Technique, that applies a lowest level to highest level range for weighting decision criteria; and Analytic Hierarchy Process (AHP), which employs a ratio scale, pairwise, for comparison of alternatives.

The Simple Multi-Attribute Rating Technique (SMART) was proposed by Edwards in 1971[15], and has become a commonly used tool for decision-makers in the real world [16]. The advantages of this technique are that: it is a simple tool to implement; its alternatives are independent; it enables the eliciting of numerical judgments; it deals with both qualitative and quantitative criteria; it creates linear form; and it is straight forward to enter the scores and weight. The downside for this technique is inability to capture all details and complexities of the real problem [17].

3.1. Uncertainty Identification

Identifying the types and sources of uncertainties that exist in the project or system is the first stage in uncertainty assessment, with documentation of uncertainties in the early stage of the project being an essential step to provide knowledge about each uncertainty. Table (1) shows uncertainty factors.

Table 1. Uncertainty factors.

Uncertainty Factor	Uncertainty Factor
Data Breach	Data Interoperability/Standardization
Data Control	Machine protection
Data Location	Latency
Data Loss or Leakage	Fault-tolerance
Insecure Cloud Services interfaces	Revision Request
Applications Security	Disaster Recovery
Cloud Services interfaces data transmission Security	Authentication Mechanism
Cloud Services interfaces development Security	Administrative Management
Remotely access Cloud services security	Permission control
Intellectual property (IP) protection	User Boundary
Encryption Levels	Quality control and assurance
Scalability	Training
Bandwidth	Standards
Cloud Service Availability	Unexpected cost/price changing
Machine Availability	Quality of Service (QoS)
System Integrity	Vender-Lock in

3.2. Uncertainty Evaluation

Uncertainty importance can be interpreted as to how this uncertainty might affect a Cloud Manufacturing in different dimensions. Measuring the importance of uncertainty can be an exhausting step in the uncertainty assessment process because of the nature of the uncertainty. To determine the importance (weight) of uncertainty in Cloud Manufacturing, multiple-criteria decision analysis (MCDA) approach was adopted in this research. This approach is a structured framework that provides advanced calculation methods for both qualitative and quantitative decision criteria [13]. MCDA is a term for methods and tools that provide decisions to decision makers in situation where there are several conflicting criteria [18,19].

Choosing the SMART technique in this phase is the most appropriate MCDM technique for this research because of the technique's advantages that mention above. By following the SMART methodology:

1- The decision maker is the expert or tool user.
2- The user selects 10 uncertainties to be analysed: Data Location, Data Loss or Leakage, Applications Security, Bandwidth, Service Availability, Machine Availability, Latency, Authentication Mechanism, Training and User Boundary.
3- The identified Cloud Manufacturing dimensions are Security, Performance, Cost, and Regulatory.
4- The user ranks the dimensions according to their decision (most important) as follows: 1) Security. 2) Performance. 3) Regulatory. 4) Cost.
5- The user rates dimensions as follows: Security = 90, Performance = 80, Regulatory = 50, Cost = 30
6- The weight for each dimension is calculated.

Table 2. Uncertainty dimensions weight

Dimension	Weight	Normalised Weight
Security	90	90/250 = 0.36
Performance	80	80/250 = 0.32
Regulatory	50	50/250 = 0.2
Cost	30	30/250 = 0.12

7- Values are assigned for each uncertainty, on each dimension, with value on scale from 0-10.
8- The score for each uncertainty is calculated by multiplying each scaled value of uncertainty into their weighted dimension, and then sum all scores for each uncertainty.

Table 3. Uncertainty total weights

Uncertainty	Security (0.36)	Performance (0.32)	Regulatory (0.2)	Cost (0.12)	Totals
Data Location	9	5	9	2	6.88
Data Loss	10	7	5	5	7.44
Applications Security	10	8	4	5	7.56
Bandwidth	5	10	5	9	7.08
Service Availability	3	10	4	8	6.04
Machine Availability	3	9	4	8	5.72
Latency	3	7	3	5	4.52
Authentication Mechanism	9	8	8	7	8.24
Training	2	6	6	7	4.68
User Boundary	7	8	8	3	7.04

4. Tool Development

The goal of the development a Microsoft Excel assessment tool is to help decision makers to identify uncertainties and assess uncertainty in Cloud Manufacturing. The tool is divided into three stages: input data stage, to reference relevant uncertainties in Cloud Manufacturing; assessment stage, to evaluate the severity of uncertainty by measuring the importance (weight) of uncertainty; and output information stage, to provide a report on uncertainties in the project that includes rating of each uncertainty.

The approach to determine uncertainty importance (weight) is based on the Simple Multi-Attribute Rating Technique (SMART). In this technique, the user is required to rank the earlier identified four dimensions of Cloud Manufacturing according to their judgment (1 is most important). Also, the user rates the dimensions by assigning numerical ratio judgments of the relative importance of attributes (on a scale from 10-100). Then, the SMART will calculate the weight for each dimension by summing importance weight and dividing by total weight. The next step is to account for each uncertainty on each dimension with a value on a scale from 0-10. The SMART will then calculate total weight for each uncertainty.

Finally, after calculating the weight for each relevant uncertainty, a report will be generated in the register page that provides information regarding uncertainty prioritisation. The prioritisation scores will be obtained from each uncertainty by the uncertainty's weight, and the uncertainty's severity will be determined in terms of Low, Medium and High. Figure 2 shows uncertainty importance page and register page.

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Uncertainty Importance

Next To Uncertainty Register

To determine the Impact of uncertainty, Please do the following steps:

Step 1: Rank the Cloud Manufacturing dimensions according to their importance (1 is most important).
Step2: Rate the dimensions by assigning Weight on 10-100 scale according to their important (10 is less important).

Dimension	Rank	Weight	Normalised Weight
Security	1	90	0.39
Performance	2	70	0.30
Regulatory	4	20	0.09
Cost	3	50	0.22

Step3: To calculate weight average of each uncertainty, input value from 1-10 scale for each uncertainty on each dimension.

Uncertainty Name	Category	Security	Performance	Regulatory	Cost	Total Weight
Data Breach	Data Security&Privacy	10	4	4	4	6.35
Data Control	Data Security&Privacy	7	4	7	4	5.43
Data Location	Data Security&Privacy	6	3	8	5	5.04
Data Loss or Leakage	Data Security&Privacy	10	5	4	4	6.65
Scalability	Technical	4	8	2	9	6.13
Bandwidth	Technical	2	9	2	7	5.22
Cloud Service Availability	Technical	2	9	3	6	5.09
Hardware Availability	Technical	2	9	3	6	5.09
CAD Drawing	Technical	1	2	3	3	1.91
Authentication Mechanism	Management	8	3	5	6	5.78
Training	Management	1	4	4	3	2.61
Standards	Management	4	3	9	2	3.70
Cost og migrate into Cloud	Management	1	2	3	8	3.00

First_page Basic_Def. Unc.DB Guide Discription Tool Assessment Prob Impact Register

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Uncertainty Register

Next To Uncertainty Mitigations

Uncertainty Name	Category	Score	Severity
Data Breach	Data Security&Privacy	16	High
Data Control	Data Security&Privacy	11	Medium
Data Location	Data Security&Privacy	11	Medium
Data Loss or Leakage	Data Security&Privacy	16	High
Scalability	Technical	11	Medium
Bandwidth	Technical	10	Medium
Cloud Service Availability	Technical	12	Medium
Hardware Availability	Technical	12	Medium
CAD Drawing	Technical	4	Low
Authentication Mechanism	Management	10	Medium
Training	Management	5	Medium
Standards	Management	7	Medium
Cost og migrate into Cloud	Management	8	Medium

Figure 2. Uncertainty Importance page and Register page.

5. Conclusions

Uncertainties in Cloud Manufacturing can be a major obstacle for Cloud Manufacturing implementation due to the nature of uncertainty that contains both unquantifiable and quantifiable factors and provides little information about the uncertainty complexity. In this paper, the Simple Multi-Attribute Rating Technique (SMART) has been presented as an approach to measure the importance (weight) of uncertainty in Cloud Manufacturing. This approach uses experts' or stakeholders' judgment to weight the importance of each uncertainty in four different dimensions. As a result, this approach delivers a rating for uncertainties that can be used to determine strategies and decisions on how to deal with uncertainty in Cloud Manufacturing. It is suggested that future research applies different assessment methods on uncertainties in Cloud Manufacturing and also assesses uncertainties in different levels, such as status of uncertainty knowledge base, in order to quantify uncertainties.

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