Is a Virtual Computer-Integrated Manufacturing System Feasible?

Son Duy Dao, Kazem Abhary, and Romeo Marian

***Abstract* — Virtual Computer-Integrated Manufacturing (VCIM) is a relatively new concept, developed to help small and medium manufacturing enterprises survive and thrive in the increasingly competitive global market. VCIM is still, conceptually, being developed. In this paper, the latest production scheduling model for VCIM systems is reported. This is the most comprehensive VCIM production scheduling model to date, which is not only capable of handling multiple product orders but also multiple objective functions under uncertainties. Besides selecting appropriate partners, i.e. component suppliers and assembly agents, to fulfil product orders, the proposed model can support collaborative shipment scheduling. The proposed production scheduling model serves as a foundation for operating VCIM systems more effectively. A supportive framework for VCIM implementation is also discussed herein.**

***Index Terms* — Collaborative shipment, production scheduling, uncertainty, virtual computer-integrated manufacturing**

I. Introduction

THE concept of Virtual Computer-Integrated Manufacturing (VCIM) has emerged recently, and inherits two characteristics: "integration" and "temporary cooperation", from two mature concepts, computer-integrated manufacturing and virtual enterprise, respectively. Computer-Integrated Manufacturing (CIM) is a manufacturing system in which all functional areas are linked together by means of computer systems to be effectively controlled and automated [1]. The integration of advanced manufacturing technologies such as Computer Numerical Control (CNC), Computer Aided Process Planning (CAPP), Automated Material Handling Systems (AMHS), Flexible Manufacturing Cells (FMC), Automated Inspection and Testing Systems (AITS), Just-In-Time (JIT) Manufacturing, etc. makes CIM system very powerful [2]. However, CIM systems can only exploit local resources and its capability is limited if the resources are not always available [3]. Virtual Enterprise (VE) is a temporary alliance of enterprises that come together to share skills, competencies as well as resources to better respond to business opportunities [4]. Through temporary cooperation and networking, VE can exploit the competitive advantages of the member enterprises. Effective cooperation helps VE produce the products with lower cost, better quality, and shorter lead time [5]. Nevertheless, the manufacturing enterprises in a VE are not fully integrated, since boundaries between them still exist; the lack of full integration limits the capability of VE. The VCIM concept inherits the good characteristics and addresses the limitations of CIM and VE concepts.

VCIM is a network of manufacturing enterprises, in which the enterprise members are willing to temporarily work together in an integrated manner, if capable and selected, to create one temporary production system to fulfil the customer order. This temporary production system as well as temporary operation will dissolve after the order is fulfilled [6]. It is noted that for the next customer order, a new temporary production system will be created, by a group of the same and/or different enterprise members. In addition, manufacturing enterprises in a VCIM system are locally and/or globally distributed.

VCIM is a new concept and is still being developed. As can be seen from the concept above, VCIM is a global manufacturing system that is integrated and flexible. The integration and flexibility (temporary cooperation) enable a VCIM system to effectively exploit the distributed manufacturing resources in today's global market. Obviously, a lot of work needs to be done to build a VCIM system, e.g. information sharing infrastructure, security, copyright, membership, quality control, effective VCIM production scheduling model and software, standardised components and products, shipment, payment, etc. A real VCIM system does not exist yet, although some theoretical work has been done [3, 7-12]. However, inspired by recent success of Alibaba model [13, 14], the VCIM researchers have a vision that VCIM systems will be the great solutions for small and medium manufacturing enterprises to do the business in near future.

Production scheduling in VCIM systems is referred to as (1) selecting manufacturing enterprises and (2) scheduling the related shipments to create a temporary production system to fulfil the given customer order. The production scheduling plays an important role in VCIM systems since it affects the quality, cost and lead time of products. To date, there have been a number of publications developing the production scheduling model for VCIM systems [3, 6-9, 11]. Nevertheless, the existing VCIM production models are not

Manuscript received: March 05, 2016; revised: March 29, 2016.
This work was supported by Australian Government in form of Endeavour Postgraduate Scholarship.
Mr Son Duy Dao, a PhD student, is with School of Engineering, University of South Australia, Australia (corresponding author to provide e-mail: son.dao@mymail.unisa.edu.au).
Prof. Kazem Abhary is with School of Engineering, University of South Australia, Australia
Dr. Romeo Marian is with School of Engineering, University of South Australia, Australia

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

comprehensive because multiple customer orders, collaborative shipment and uncertainty are not taken into account.

In this paper, the most comprehensive VCIM production scheduling model to date is first reported, and then some discussion is presented.

II. Latest VCIM Production Scheduling Model

After receiving product orders, the VCIM system decomposes the orders into a number of pre-defined standard product components or subassemblies (called components, for short, hereafter) which can be independently produced; and then it does the VCIM production scheduling by (1) selecting some component suppliers to produce the required components, (2) selecting some assembly agents to assemble the required products and (3) scheduling the shipments to transport the components and products to the required destinations; so that a temporary VCIM production system can be formed to fulfil the customer orders. To take advantage of collaborative shipment and to facilitate the global optimisation, an innovative production scheduling model for VCIM systems is developed herein as follows.

Consider:

- A VCIM system has a number of assembly agents as well as component suppliers, which are both globally and locally distributed.
- The VCIM system is capable of providing a number of products for customers worldwide and each product is made by assembling a number of components.
- Each component supplier can provide certain components for certain products.
- Each assembly agent can do final assembly for certain products.
- In the current planning horizon, several customer orders with the same and/or different products are being requested.

Determine:

- Allocation of the required components of the requested products to the component suppliers?
- Allocation of the requested products to the assembly agents?
- The related component and product shipping schedules?

So that:

A temporary VCIM production system can be formed to simultaneously fulfil all of the customer orders with (1) minimum total cost, (2) minimum average completion time and (3) maximum average reliability, while all of the given constraints are satisfied.

Conditions:

- Cost and release time of each product component provided by different component suppliers are different from one another but known in advance.
- All product components can be independently produced.
- Assembly cost and time of each product assembled in different assembly agents are also different but given in advance.
- Shipping cost and time between any two locations are different from each other but known in advance.
- All component release times, product assembly times and shipping times are stochastic parameters with known distribution functions, mean values as well as standard deviations.
- One product is assembled in one assembly agent only.
- One assembly agent is capable of assembling a certain number of products.
- All component suppliers and assembly agents have enough resources such as labour, material, etc. to perform their designed functions 24 hours a day, 7 days a week.

The proposed VCIM production scheduling model is illustrated in Fig. 1 with a typical production scheduling solution to fulfil 8 customer orders (C1, C2 … C8). The system has 14 assembly agents (A1, A2 … A14) and 20 component suppliers (S1, S2 … S20), distributed worldwide. In the illustrated solution, component suppliers S2, S5, S6, S9 and assembly agent A13 were selected to serve customers C1-C3; component suppliers S7, S18, S20 and assembly agent A14 were selected to fulfil the customer orders C4-C6; and component suppliers S10, S16, S20 and assembly agent A2 were selected to serve customers C7-C8. Two kinds of shipments, separate shipment and collaborative shipment, were used in the solution as shown in Fig. 1. It is noted that the separate shipment herein refers to a shipment carrying the component(s) produced by only one component supplier or a shipment carrying finished product(s) to only one customer. In contrast, the collaborative shipment means a shipment carrying the components made by more than one component supplier or a shipment carrying finished products to more than one customer. Examples of separate and collaborative shipments are shown in Fig. 1. Due to space limit, mathematical version of the proposed model is not presented herein; it will appear in the authors' future publication.

III. Discussion

Small and medium size enterprises (SMEs), a symbol of innovation and competition in various industrial sectors, play an important role in any economy [15, 16]. In today's global market, SMEs face fierce competition by large enterprises that have huge resources. To deal with the competition, SMEs usually concentrate on their core competence, and outsource some non-core activities [15]. Cooperation among SMEs worldwide to exploit the distributed resources is a critical strategy to enhance their competitiveness [17]. Alibaba.com is a great platform that enables SMEs to do business efficiently anywhere in the world [18]. The philosophy that makes Alibaba Company so successful is as follows:

"*Small and medium-size enterprises are like grains of sand on a beach. The Internet can glue them together. It can make them into an invincible force that is able to go up*

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

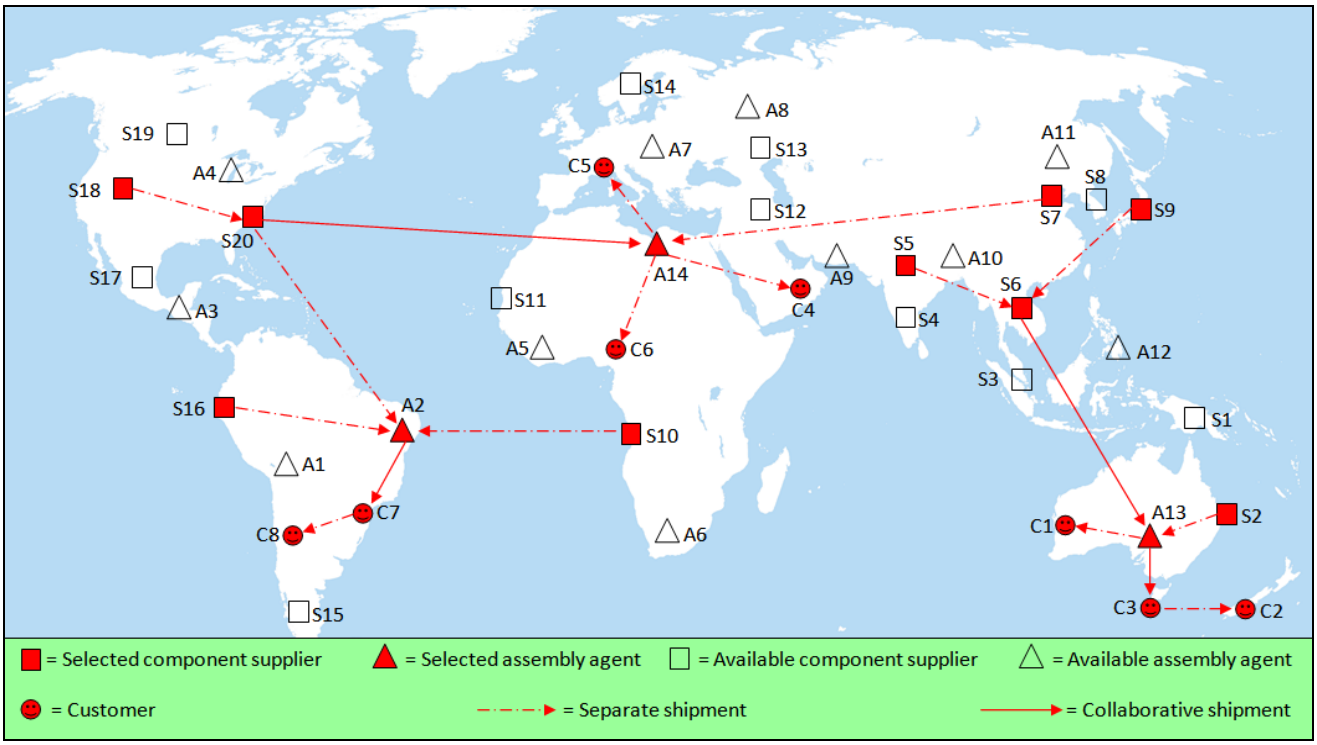

Fig. 1: Proposed VCIM production scheduling model

against the big stones. The virtue of the Internet is that it uses small to compete with big, it uses fast to compete with slow." Jack Ma, the founder of e-commerce giant Alibaba [13].

Alibaba.com is the e-commerce giant, running B2B (business to business), B2C (business to customer) and C2C (customer to customer) e-marketplace that connects small and medium-size buyers and suppliers all over the world [19]. Jack Ma, a former English teacher, started Alibaba Company in 1999 with just $60,000. But now, Alibaba's profits surpass those of Ebay and Amazon combined; only three technology companies in the world, i.e. Microsoft, Google and Apple, are bigger [14].

With Alibaba.com, barriers all around the world dissolve; anyone with Internet access has the opportunity to import, export, build commercial alliances, and trade with anyone else, anywhere in the world. In addition, customers can have a high degree of participation in the design of the products they purchase [20]. There is no doubt that the Alibaba.com platform can support VCIM implementation in general and the proposed VCIM production scheduling model in particular, in which component suppliers and assembly agents could be SMEs distributed worldwide. Of course, more work needs to be done to validate the concept and make VCIM systems a reality. However, the authors believe that a VCIM system will be feasible in near future. That is why they are currently working on a research project to make VCIM happen. New progress regarding VCIM systems will be reported in the authors' future publications.

IV. Conclusion

In this paper, an innovative production scheduling model for VCIM systems has been proposed. The developed model, the most comprehensive VCIM production scheduling model to date, is not only capable of handling multiple product orders simultaneously but also multiple objective functions, under uncertainties of component release times, assembly times as well as shipping times. In addition, besides selecting appropriate partners, i.e. component suppliers and assembly agents, to fulfil product orders, the proposed model can support collaborative shipment scheduling. The feasibility of the proposed VCIM production scheduling model has also been discussed. It has been concluded that Alibaba.com platform, run by e-commerce giant Alibaba, is the necessary (missing) link which can support implementing the proposed VCIM production scheduling model, and a VCIM system will be feasible in near future. In fact, there is, conceptually, no obstacle in the VCIM model.

In future work, the authors will present the mathematical version of the proposed model, in which all aspects of the model are expressed in greater details. In addition, a robust optimisation approach will be developed to solve the production scheduling problem in the developed model.

References

[1] Miller, F.P., A.F. Vandome, and J. McBrewster, *Computer-integrated manufacturing*, 2010, Mauritius: VDM Publishing House.

[2] Nagalingam, S.V. and G.C.I. Lin, *Latest developments in CIM*. Robotics and Computer-Integrated Manufacturing, 1999. **15**(6): p. 423-430.

[3] Wang, D., *The development of an agent-based architecture for virtual CIM*, 2007, University of South Australia, Adelaide: Adelaide.

[4] Camarinha-Matos, L.M. and H. Afsarmanesh, *The virtual enterprise concept*, in *Infrastructures for virtual enterprises*

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

– *Networking industrial enterprises*, L.M. Camarinha-Matos and H. Afsarmanesh, Editors. 1999, Kluwer Academic Publishers: The Netherlands. p. 3-14.

[5] Huang, B., et al., *A framework for virtual enterprise control with the holonic manufacturing paradigm.* Computers in Industry, 2002. **49**(3): p. 299-310.

[6] Zhou, N., et al., *Development of an agent based VCIM resource scheduling process for small and medium enterprises*, in *International MultiConference of Engineers and Computer Scientists*, 2010: Hong kong. p. 39-44.

[7] Wang, D., S.V. Nagalingam, and G.C.I. Lin, *Development of an agent-based virtual CIM architecture for small to medium manufacturers.* Robotics and Computer-Integrated Manufacturing, 2007. **23**(1): p. 1-16.

[8] Wang, D., S.V. Nagalingam, and G.C.I. Lin, *Development of a parallel processing multi-agent architecture for a virtual CIM system.* International Journal of Production Research, 2004. **42**(17): p. 3765-3785.

[9] Nagalingam, S.V., G.C.I. Lin, and D. Wang, *Resource scheduling for a virtual CIM system*, in *Process Planning and Scheduling for Distributed Manufacturing*, L. Wang and W. Shen, Editors. 2007, Springer London. p. 269-294.

[10] Lin, G.C.I., S.V. Nagalingam, and J. Zhou, *Virtual CIM for globalised manufacturing*, in *International Conference on Engineering and Technological Sciences* 2000: Beijing, China p. 319-327.

[11] Dao, S.D., K. Abhary, and R. Marian, *Optimisation of resource scheduling in VCIM systems using genetic algorithm.* International Journal of Advanced Research in Artificial Intelligence, 2012. **1**(8): p. 49-56.

[12] Dao, S.D., K. Abhary, and R. Marian, *A stochastic production scheduling model for VCIM systems.* Intelligent Industrial Systems, 2016. **2**(1): p. n/a.

[13] Liu, S. and M. Avery, *Alibaba: the inside story behind Jack Ma and the creation of the world's biggest online marketplace*, 2009, New York: HarperCollins e-books.

[14] Waite, S., *Record-breaking Alibaba allocates to happy few*, in *FinanceAsia (Deal of the month: October)* 2014, Haymarket Media, Inc. p. 8-9.

[15] Kumari, S., et al., *A multi-agent architecture for outsourcing SMEs manufacturing supply chain.* Robotics and Computer-Integrated Manufacturing, 2015. **36**: p. 36-44.

[16] Angilella, S. and S. Mazzù, *The financing of innovative SMEs: A multicriteria credit rating model.* European Journal of Operational Research, 2015. **244**(2): p. 540-554.

[17] Iturrioz, C., C. Aragón, and L. Narvaiza, *How to foster shared innovation within SMEs' networks: Social capital and the role of intermediaries.* European Management Journal, 2015. **33**(2): p. 104-115.

[18] Yazdanifard, R. and M.T.H. Li, *The review of Alibaba's online business marketing strategies which navigate them to present success.* Global Journal of Management And Business Research, 2014. **7**(9): p. 33-39.

[19] Qing, H.H. and Z.S. Xue, *A model for value-added e-marketplace provisioning: Case study from Alibaba.com*, in *Software Services for e-Business and e-Society*, C. Godart, et al., Editors. 2009, Springer Berlin Heidelberg. p. 65-72.

[20] Schepp, B. and D. Schepp, *The official Alibaba.com success guide insider tips and strategies for sourcing products from the world's largest B2B marketplace*2010, Hoboken, N.J.: John Wiley & Sons.

ISBN: 978-988-14048-0-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)