ISSN 2029–2236 (print)
ISSN 2029–2244 (online)
SOCIALINIŲ MOKSLŲ STUDIJOS
SOCIETAL STUDIES
2011, 3(1), p. 95–106.

FACTORS THAT INFLUENCE THE SUCCESS OF THE PRACTICAL IMPLEMENTATION OF VIRTUAL CELLULAR MANUFACTURING SYSTEMS

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Received 7 February, 2011; accepted 25 March, 2011

Abstract. *The virtual cellular manufacturing systems (VCMS) are the most interesting, from an evolutional point of view, systems. They present a further development of the classical cell and flexible manufacturing concepts, brought to a higher level by the specific, new way of workstations (Automated Technological Modules–ATM) deployment. The practical implementation of Virtual Cellular Manufacturing Systems (VCMS) and every new type of organization faces a large number of obstacles and constraints. The first steps are to analyze what factors will affect the success of the implementation and to assign a numerical value to each factor when possible. This paper outlines nine influential factors and classifies the two most important of them.*

Keywords: *Virtual cell, Virtual Cellular Manufacturing System.*

ISSN 2029–2236 (print), ISSN 2029–2244 (online)
http://www.mruni.eu/lt/mokslo_darbai/SMS/
http://www.mruni.eu/en/mokslo_darbai/SMS/

Introduction

The most important requirement to the modern, intelligent production systems is that they should maintain flexibility in order to satisfy the fluctuations of the market demand and to present innovative products immediately.[1] Solberg's definition about the production systems of the future, made in the 80's is still valid today—they must have the "innate ability to respond, promptly and correctly, to changes in requirements."[2]

The concept of cellular manufacturing, which uses as a foundation the principles of the group technology has a vast implementation in the modern manufacturing systems and aims the satisfaction of these requirements. The cellular manufacturing systems evolution engages three types of systems:

– classical cellular manufacturing systems;
– dynamical cellular manufacturing systems;
– virtual cellular manufacturing systems.

The classical cellular manufacturing systems (CCMS) consist of physically defined cells of machines and staff responsible for the production of a product family. The negatives are connected to the not sufficient machine utilization and low effectiveness of the system during demand and product mix changes.

The dynamical cellular manufacturing systems (DCMS) are not often used. They can be found only in a system utilizing small and thus comparatively easy movable machines, allowing low cost regrouping.

The virtual cellular manufacturing systems (VCMS) are the most interesting, from an evolutional point of view, systems. They present a further development of the classical cell and flexible manufacturing concepts, brought to a higher level by the specific, new way of workstations (Automated Technological Modules–ATM) deployment.[3] According McLeans' definition[4], the virtual cell cannot be identified as a fixed, physical grouping of workstations (ATM), but as data files and processes in a controller. Otherwise the virtual cell represents a logical grouping of resources controlled by a processor and needed for the production of a particular batch of parts.

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1 Fung, R. Y. K.; Feng, L.; Zhibin, J.; Wong, T. N. A Multi-stage Methodology for Virtual Cell Formation Oriented Agile Manufacturing. *The International Journal of Advanced Manufacturing Technology.* 2008, 36(7-8): 798−810.

2 Solberg, J. J.; Anderson, D. C.; Barash, M. M.; Paul, R. P. *Factories of the Future: Defining the Target.* A report of research study conducted under National Science Foundation Grant MEA8212074. Purdue University, West Lafayette, IN, 1985 January 1.

3 Dakov, I. *Proizvodstven Ingenering* [Production Engineering]. PH Ljuren, Sofia: BG, 2003; Dakov, I.; Lefterova, T.; Petkova, A. Layout and Production Planning of Virtual Cellular Manufacturing Systems for Mechanical Machining. *The Journal of Economic Asymmetries.* 2010, 7(1); Lefterova, T. K. *Research and Improvement of the Spatial Deployment of the Virtual Cellular Manufacturing Systems.* Summary of Doctoral Dissertation, Technical University Sofia, 2004.

4 McLean, C. R., Bloom, H. R.; Hopp, T. H. The Virtual Manufacturing Cell. *Proceedings of Fourth IFAC/IFIP Conference on Information Control Problems in Manufacturing Technology.* Gaithersburg, MD, October 1982.

The characteristics of a VCMS combine a very large variety of produced parts, a so-called conditionally product oriented system, universal workstations (ATM), situated in a specific equally dispersed layout, a combined parallel-consecutive sequence of the operations and a regulated movement of the semi-finished parts.

The successful practical implementation of a VCMS in particular, or commonly the implementation of a new manufacturing system depends on the determination of factors which influence that implementation. To determine the factors that influence the successful implementation of a VCMS, we propose a heuristic approach, based on the specifics of the spatial and time organization of the manufacturing process in a VCMS.

1. Specifics of the Form of the Production Organization in the VCMS

The specifics of a VCMS are determined by the eight so-called characteristic signs of the form of production organization (FPO), typical for VCMS.[5] The values of the eight characteristic signs for the Virtual Manufacturing FPO are as follows:

1) manufacturing units'(system) specialization—conditionally product;
2) workplaces' (ATM) specialization degree—universal with CNC;
3) workplaces (ATM) layout—equally dispersed;
4) work jobs' repetition—not determined or periodical;
5) time sequence of the duration of the operations from a work job—none;
6) time sequence of the consequently starting work jobs—usually combined (parallel-consequent) and consequent only rarely for small batches;
7) size of the transportation units of semi-finished parts—can be all known sizes e.g., single part transportation, transportation devices' lots or whole order transportation;
8) type of movement between the workstations—regulated.

The specific values of the characteristic signs of the different forms of production organizations are shown in table 1.

Table 1. Characteristic signs of the different forms of production organizations[6]

Characteristic Sign	Value of the characteristic sign	Form of production organization (FPO)				
		Group	Flow line	Product	Product-group	Virtual cellular
Manufacturing units'(system) specialization	Process Product	+ -	- +	- +	- +	- +
Workplaces' specialization degree	Universal Specialized Special	+ - -	- - +	- + -	+ - -	+ - -

5 Dakov, I., *supra* note 3; Dakov, I., *et al*., *supra* note 3.

6 Dakov, I., *supra* note 3.

Workplaces layout	Group; Product-linear; Product non-linear; Mixed product-group; Equally dispersed;	+ - - - -	- + - - -	- + + - -	- - - + -	- - - - +
Work jobs' repetition	None; Periodic Rhythmic;	+ - -	- - +	- + -	+ + -	+ + -
Time sequence of the duration of the operations from a work job	Not sequenced; Sequenced;	+ -	- +	+ -	+ -	+ -
Time sequence of the consequently starting work jobs	Consequent; Parallel; Parallel-consequently;	+ - -	- + -	+ - +	+ - +	- - +
Size of the transportation units of semi-finished parts	Single part; Transport batches; Full batches (orders);	+ + +	+ + +	+ + +	+ + +	+ + -
Type of movement between the workstations	Not regulated; Regulated; Strictly regulated;	+ - -	- + -	- + -	- + -	- + -
Practical implementation of the FPO		Group Sector	Flow lines	Product Sector, technologically oriented line, Flexible automated line	Flexible automated production systems, /flexible automated sectors/	VCMS

2. Grouping of the Characteristic Signs of the Form of Production Organization

The determination of influential factors follows after a careful grouping and study of the characteristic signs from above. This grouping should ease the complete review of all possible factors and help their prioritization.

2.1. Signs' Grouping that Uses the Principles of Spatial and Time Organization of the Manufacturing Process

The first proposed grouping uses as a guide the principles of the spatial and time organization of the manufacturing process[7]:

a) specialization principle—related to the specialization of the manufacturing unit (sign 1);

b) semi-directional principle—refers to the workplaces layout (sign 3);

c) proportion principle—no connectivity with a particular sign;

d) parallel principle—principle that directly influences the time sequence of the consequently starting work jobs and also indirectly influences the time sequence of the work jobs duration and size of the transportation units of semi-finished parts;

e) rhythm principle—no connectivity with a particular sign;

f) flexibility principle—this principle influences the specialization of the manufacturing unit (sign 1), which can be determined by the flexibility coefficient. The specialization of the workplaces (sign 2) is directly correlated with their flexibility and as a measurement tool the manufacturing capability of the machine or the weighted manufacturing capability can be utilized. The capabilities of the transport system for handling the semi-finished parts (Sign 8) depends on its abilities to perform movements in any desirable direction and also the load capacity of each transport element.

2.2. Grouping of the Characteristic Signs, Regarding the Different Structural Elements of the Manufacturing Subsystem

The characteristic signs can also be grouped as regarding the structural elements of the manufacturing subsystem:

a) regarding workplaces—workplaces' specialization degree;

b) regarding manufacturing units—manufacturing units specialization, workplaces layout, work jobs' repetition, time sequence of the work jobs duration, size of the transportation units of semi-finished parts, between the workstations movement.

The described above grouping offers a conditional separation of the signs as each sign is connected to a structural element. An example is the time sequence of the work jobs (operations) duration which influences the deployment of the workplaces. This sign only determines if the deployment should be product-linear or product-non-linear, but this is enough to classify it as a manufacturing units' influential. Size of the transportation units of semi-finished parts defines in a larger scale the characteristics of the transport system in the specified manufacturing unit and because of that is considered to be one of the signs corresponding to the manufacturing units, but if one decides to present the transport system as a unit of different transport modules (for example self guided vehicles–SVG) and thus every SVG as a different workplace, then the sign should be regarded as one concerning the workplaces. This shows that the grouping is approximate

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7 Dakov, I., *supra* note 3.

and aims to divide the signs into separate divisions. Then it is possible to define a factor influencing the characteristics of each structural element.

3. Determination of the Factors Influencing the Practical Implementation of VCMS

In order to define factors that influence the successful implementation of VCMS it is necessary to analyze the described above groupings and to estimate all the possible aspects of that implementation, specifically concerning the manufacturing systems for mechanical machining. The particular study of every grouping will result in the definition of factors, some of which will be repetitive to ones from the other groupings. The aim is to finally define non-repetitive factors which influence the system and to define numerical values for each of the factors.

The concept of the virtual manufacturing cell is an ancestor to the concept of the classic manufacturing cell. Thus, in order to define all the influential factors one should also consider the factors that influence the implementation of the classic cells, at least as a starting point.

The implementation of classical manufacturing cells defines a set of questions regarding which products and what kind of production systems are the most suitable for the implementation of classic cells (CC)[8]. The factors that are usually taken into account are the production system complexity, the size of the batches, the amount of the different product families and the size of the enterprise. According grouping two, all these factors can be connected to the signs concerning manufacturing units, except one—the size of the enterprise.

Amount of the different product families is significant because it is expected that the equally dispersed layout, typical for the VCs brings the best advantage to the VCMS when the products tend to vary a lot. To measure that variety the quantity of the each different part family per year is commonly used.

The factor complexity of the manufacturing system. It is determined by the complexity of the produced parts which are divided into four groups[9]:

- single-component, relatively simple parts;
- single-component, relatively complicated parts;
- multi-component, relatively simple units;
- multi-component, relatively complicated units.

Regarding VCMS and particularly manufacturing units for mechanical machining, the two types concerning units can be automatically taken out of account because of the specifics of the structural unit of the system. The factor itself then becomes obscure and cannot be used, at least at the beginning, to define any constraints when choosing if an enterprise presents possibilities for a VC implementation. This factor will be studied in

8 Dale, B. G. Benchmarking Measures for Performance Analysis of Cells. *Handbook of Cellular Manufacturing Systems*. John Wiley and Sons, Inc., 1999.

9 *Ibid*.

a future research regarding the possible benefits of a VC implementation by the use of simulation methods.

The average batch size of the orders is a factor which will influence the implementation of VC as much as the volume flexibility of the VCMS is concerned. The above mentioned quantity of each different part family per year includes this factor and a separate quantity measurement tool for that factor can be specified later, only if necessary, after the implementation of a simulation technique and obvious proof that the quantity of the part families plays a very essential role in the success of a future VCMS.

The factor size of the enterprise or its machines number plays an important role in its production floor layout planning. It is usually assumed that the greater quantity of machines constraints the material flow in a single piece and small batches order oriented facilities with a traditional layout. Then it is necessary to find, if possible, a critical number of machines which defines a border separating the traditional from the VC organized layout. The specific number of the machines and thus the machine capacity of the unit are of a great interest.

When investigating the *first grouping*, the first sign is the *specialization of the manufacturing unit*. Quantity measurement tool—coefficient of product specialization.

The second point of that grouping stands for semi-directional principle. In order to fulfill it, the workplaces must be situated one right after the other, according the product technology, thus assuring a one directional flow with lowest possible transportation. This cannot be defined as a factor because the nature of the VCMS naturally assures that principle with its typical equally dispersed workplaces layout.

The third point—proportion principle depends on the time consumption of the products planned for production and the time availability of the manufacturing unit. It is obvious that for an existing enterprise the capacity of the manufacturing unit was enough to fulfill the orders it has already delivered but it would be very interesting to investigate if the *capacity of the manufacturing unit* is a factor influencing the implementation of the VCs. Measurement tools for the effective utilizations of the machines are the coefficients of intensive and extensive use of the machines.

The parallel principle guides to factors connected to the technological specifics of the production and also to the specifics of the transport system. The technological specifics are connected with the factor complexity of the manufacturing system, which is defined by the complexity of the products and was defined above. The specifics of the transport systems are defined by its flexibility and *load capacity*. In this case the term load capacity means the maximal capability of the system to physically move parts or semi-finished goods from one workplace to the next. Therefore as a measurement tool, the maximal load which can be transported between two workstations by the weakest point of the system should be used. The last one must be considered only if the transport system has different load capacities between the different workstations. Practically, the meaning of the above mentioned considerations describes the maximal possible number of parts in a transport batch.

The flexibility of the transport system should be described as the possibilities available for different routings of the transport batches and depends on the possibilities of the transport system to maintain the movement from one workstation to a randomly chosen workstation and also to maintain the crossing of material flows. Usually the both of the conditions are present in the existing manufacturing units, but it is useful to have information on the question when implementing VCs in a production system. In order to have a measurement tool we propose the following division:

- systems not allowing transportation in all directions and without crossing (grade 1);
- systems not allowing transportation in all directions and with crossing (grade 2);
- systems allowing transportation in all directions and without crossing (grade 3);
- systems allowing transportations in all directions and with crossing (grade 4).

Regarding principle five (e), there is no possible factor to be determined.

Regarding the *second grouping (3.2)* the smallest structural element of the manufacturing subsystem of the industrial enterprise is characterized by its specialization degree. It is influenced by the capability of the machines used to create the workplaces. The manufacturing capabilities of the machines are described by their specific flexibility as for the planned for production variety of goods and as its operating capacity. As for the factor we will use the term *specific flexibility* of the machines and for a quantity measurement tool the weighted manufacturing capability of the machine[10]:

$$M_{mp}^{WPC} = \frac{\sum_{j_p=1}^{O_p} M_{mj_p}^{WPC}}{O_p} \qquad (1)$$

where:

j_p – operation number j from the production cycle of part p;

$M_{mj_p}^{WPC}$ – weighted manufacturing capability of machine m to fulfill operation j from the production cycle of part p;

O_p– the total amount of the operations from the production cycle of part p;

$$\mathbf{M_{mj_p}^{WPC}} = \frac{\mathbf{X_{mj_p}}}{\mathbf{t_{mj_p}}} \qquad (2)$$

where:

X_{mjp} —capability of machine m to fulfill the j[th] operation and X has a discrete (Boolean) value, e.g. 1 if it is possible or 0 if not;

t_{mjp} —the time needed for machine m to fulfill the j[th] operation from the production cycle of part p;

10 Vakharia, A. J.; Askin, R. G.; Selim, H. M. Flexibility Considerations in Cell Design. *Handbook of Cellular Manufacturing Systems*. John Willey and Sons, Inc, 1999.

The weighted value of the machine capability has been chosen because of the fact that the machines usually associated with a VCMS are computerized, universal and very flexible. The flexibility of these machines defines the need of a time incorporation in the formula, because these machines are in general capable of maintaining most of the operations.

The second part of the grouping (3.2) regards the specifics of the workstations' layout. As a further improvement we must consider the *characteristics of the work-floor* and regard them as a separate factor. As a possible measurement tool we propose the quantity of the unavailable for use floor space as a part of the total floor space (as a ratio). This may be further developed as a division of the floor space into equal-sized patches as the size of the patch must be equal to the size of the largest workstation.

The above mentioned two types of grouping (3.1 and 3.2) of the signs that determine the form of the manufacturing organization, typical for VCMS aim to define and widely analyze all the possible factors that may influence the practical implementation of VCMS. Some of them are of a greater importance and offer a good possibility for a measurement tool assignment. The measurement tool will be useful in order to set a possible critical for the implementation values, e.g. to create numerical requirements for the implementation of a VCMS.

The defined factors and their measurement tools are shown in table 2.

Table 2. Influential factors of the practical implementation of VCMS

№	Factor	Measurement tool
1	Specific machine flexibility	Weighted capability of the machine [-]
2	Variety of products	Number of the different part types [pcs. per year]
3	Average size of the batches	Average amount of the parts in a batch [pcs.]
4	Total amount of production machines	Amount of the production machines of each type [pcs.] and
5	Specialization of the manufacturing unit	Coefficient of product specialization [-]
6	Production capacity	Time for operations during the period for each technological type of machines (e.g. drilling, milling, etc.) [hours per year]
7	Loading capacity of the transport devices	Maximal allowance for the weight of the load [kg]
8	Flexibility of the transport system	None – for a measurement tool a conditional grade scale of the possibilities to be used. The grades should be from 1 to 4, as 1 should be the lowest grade, meaning that the system cannot move parts between all the workstations and there is no possibility for flows crossing.
9	Specific characteristics of the work floor	Accessibility the places for machine positioning[-]

The precise evaluation of the limiting conditions for the practical implementation of VCMS is a complex job and exact numeric values can be set only if based on a variety of practical experiments. Presently it is useful to set only the basic constraints which are connected to the definitions for and the specifics of VCMS, which if not satisfied will make the implementation of VCs totally unacceptable. The major constraints are connected to the main advantages of the VCMS as flexibility, approximately equal to that of the group form of production organization (process layout) and at the same time the high intensity of the production process, approximately equal to that of the product type of production organization. The reasons for these advantages are the specifics of the machines used in VCMS and particularly ATMs, which are very flexible and have low set up times and also the equally dispersed layout of the modules on the production floor which ensures a low volume of transportation jobs. For a full use of the last advantage there must be a possibility for an easy handling of the parts between the workstations, e.g. a flexible system for transportation.

The above mentioned characteristics of VCMS help to distinguish the most important factors, which are:

- Specific flexibility of the machines;
- Flexibility of the transport system.

As these are the most important influential factors, it is important to set limiting conditions for them at least. The setting of limiting conditions for all the other factors would be of a great use during the implementation of a VCMS, but these conditions cannot be estimated at present.

From the practitioners' point of view, the following factors are of a great interest:

- Variety of the produced parts (details machined);
- Types and amount of the production machines (ATM).

Unfortunately, the exact estimating of limiting values for the measurement tools, before a wide practical implementation of VCMS and collection of sufficient statistical data is hardly achievable. It is obvious that regarding the number of the machines the limitations can be set to at least few machines of each type and only the type with the highest productivity to be set to one.

Conclusions

The influential factors for the successful practical implementation of VCMS for mechanical machining were determined through a complete analysis and grouping of the characteristic signs of the form of production organization. The determination of the importance and the exact measurement tool for each factor gives an opportunity to estimate the limiting conditions for a VCMS practical implementation. The estimating of these limitations is time and effort consuming, because of the need of statistical data, while the experience of the practical implementation of VCMS worldwide is insufficient.

The scientific research, the results of which are presented above was financed by the Internal proceedings of TU–Sofia.

References

Dakov, I. *Proizvodstven Ingenering* [Production Engineering]. Sofia, BG: PH Ljuren, 2003.

Dakov, I.; Lefterova, T.; Petkova, A. Layout and Production Planning of Virtual Cellular Manufacturing Systems for Mechanical Machining. *The Journal of Economic Asymmetries*. 2010, 7(1).

Dale, B. G. Benchmarking Measures for Performance Analysis of Cells. *Handbook of Cellular Manufacturing Systems*. John Wiley and Sons, Inc, 1999.

Fung, R. Y. K.; Feng, L.; Zhibin, J.; Wong, T. N. A Multi-stage Methodology for Virtual Cell Formation Oriented Agile Manufacturing. *The International Journal of Advanced Manufacturing Technology*. 2008, 36(7-8): 798−810.

Lefterova, T. K. *Research and Improvement of the Spatial Deployment of the Virtual Cellular Manufacturing Systems*. Summary of Doctoral Dissertation, Technical University Sofia, 2004.

McLean, C. R.; Bloom, H. R.; Hopp, T. H. The Virtual Manufacturing Cell. *Proceedings of Fourth IFAC/IFIP Conference on Information Control Problems in Manufacturing Technology*. Gaithersburg, MD, October 1982.

Solberg, J. J.; Anderson, D. C.; Barash, M. M.; Paul, R. P. *Factories of the Future: Defining the Target*. A report of research study conducted under National Science Foundation Grant MEA8212074, Purdue University, West Lafayette, IN, January 1, 1985.

Vakharia, A. J.; Askin, R. G.; Selim, H. M. Flexibility Considerations in Cell Design. *Handbook of Cellular Manufacturing Systems*. John Willey and Sons, Inc, 1999.

VEIKSNIAI, TURINTYS ĮTAKOS PRAKTINIO VIRTUALIŲ TINKLINIŲ GAMYBOS SISTEMŲ ĮGYVENDINIMO SĖKMEI

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Santrauka. *Virtualios tinklinės gamybos sistemos (VTGS) evoliucijos požiūriu yra vertos ypatingo mokslinio nagrinėjimo. Virtualios gamybos sistemos – tolesnis klasikinės tinklinės bei lanksčios gamybos sąvokų plėtojimas, paskatintas naujo lygio specifinių darbo vietų išdėstymo. Pagal klasikinį apibrėžimą virtualios tinklinės gamybos sistemos virtuali ląstelė (elementas) turi būti suvokiama ne kaip stacionarių fizinių automatizuotų darbo vietų grupavimas, o kaip duomenų rinkinių bei procesų valdymas.*

Esama nemažai problemų bei kliūčių praktiškai įgyvendinant VTGS. Pradžioje turėtų būti nustatyti veiksniai, kurie gali paveikti įgyvendinimą, bei atliekama jų analizė. Analizę lengviau atlikti, jei pavykta kiekvienam veiksniui priskirti skaitmeninę vertę. Straipsnyje pabrėžiama, kad VTGS specifiką lemia gamybos organizavimo formų (GOF) aštuoni būdingi požymiai arba ypatybės. Veiksniai, turintys įtakos sėkmingai praktiškai įgyvendinant mechaninę virtualią tinklinę gamybos sistemą, gali būti nustatyti atliekant visą būdingų *požymių analizę ir grupavimą. Taip grupuojant lengviau išsamiai apžvelgti galimus veiksnius ir juos išdėstyti pagal svarbą. Požymiai grupuojami į dvi kategorijas: 1) grupuojama, remiantis gamybos proceso organizavimo erdvės ir laiko aspektu; 2) grupuojama pagal skirtingus gamybos posistemės struktūrinius elementus. Kiekvienai ypatybių grupei turėtų būti priskirta po veiksnį. Šio straipsnio autoriai nustato devynis veiksnius bei suklasifikuoja du svarbiausius iš jų. Šie veiksniai – tai gera pradžia statiškam VTGS galimybės įgyvendinimui įvertinti.*

Nustačius kiekvieno veiksnio reikšmę bei tikslaus įvertinimo įrankį, galima numatyti praktinio VTGS įgyvendinimo trukdžius. Statistiniai duomenys reikalingi tiksliai nustatyti trūkumus. Tokiems duomenims surinkti sugaištama daug laiko bei padedama daug pastangų. Praktinio VTGS įgyvendinimo patirtis pasaulyje yra nepakankama. Statistinių duomenų trūkumas gali būti kompensuojamas, taikant imitacinį modeliavimą ir analizę. Imitacinis modelis galėtų tapti šio tyrimo tęsiniu ir padėti nustatyti kiekvieno veiksnio matavimo įrankio vertes.

Reikšminiai žodžiai*: virtuali tinklinės gamybos sistema, gamybos organizavimo formos.*

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