

Framework for Improving Manufacturing "Implicit Competitiveness" by Enhancing Monozukuri Capability

Takahiro Togawa, Nguyen Huu Phuc, Shigeyuki Haruyama, Oke Oktavianty

Abstract—Our research focuses on a framework which analyses the relationship between product/process architecture, manufacturing organizational capability and manufacturing "implicit competitiveness" in order to improve manufacturing implicit competitiveness. We found that 1) there is a relationship between architecture-based manufacturing organizational capability and manufacturing implicit competitiveness, and 2) analysis and measures conducted in manufacturing organizational capability proved effective to improve manufacturing implicit competitiveness.

Keywords—Implicit competitiveness, QCD, Monozukuri capability.

I. INTRODUCTION

JAPAN'S manufacturing industry faces a worrying future. Global Competitiveness Report in 2016 lowered Japan's competitiveness rank from 6th in 2015 to 8th in 2016 as shown in Fig. 1 [1]. Fig. 2 also shows that IMD World Competitiveness Center (IMDWCC) also brought down Japan competitiveness from 21st in 2014 to 26th in 2016 [2]. Taking those concerns in account, this research aims to investigate a strategy to increase the "implicit competitiveness" which is essential to boost company's profitability.

Japanese literatures on manufacturing strategy offered theory called "Monozukuri System" initially developed by Takahiro Fujimoto who considered manufacturing itself as a strategy to improve profitability [3], [4]. Fig. 3 shows the structure of the strategy. There are four main components: Manufacturing organizational capability, implicit competitiveness, explicit competitiveness and profitability.

The "organizational capability" is the power of an organization to survive and grow. This power is company-specific and obtained through activities and practices that are deemed important and conducted regularly at the company. The "manufacturing organizational capability" is defined as the organizational ability to establish the internal structures and process, particularly in the development and production sites [10]. This manufacturing organizational capability is not only company-specific but also sometimes, compared to other companies, unique at the level of even a factory.

The competitiveness is a multidimensional concept with many perspectives and views [11]. The implicit competitiveness is the capability in manufacturing process that 1) cannot be observed directly from customers, and 2) decides the performance of product development and production, such as production quality, production cost, development productivity, product productivity, development lead time, production lead time and so on.

The explicit competitiveness is defined as the performance that can be observed and evaluated by customers. They are factors that are directly connected with customers such as sales and consumption. Examples of them are product prices, product specifications, delivery date, brand, service, market share, etc. [12].

The earning capability is the ability to earn the aggregate profitability resulted from the performance of all above-mentioned elements [13]. The indicators can be sales margin, profit margin, return on equity, cash flow margin, etc.

The Manufacturing Strategy Theory consists of two main features as shown in Fig. 4.

Firstly, the four components (manufacturing organizational capability, implicit competitiveness, explicit competitiveness and profitability) have the causal effects according the mentioned order. Secondly, the structure of Monozukuri Strategy in Japan (Monozukuri=Japanese way of manufacturing) has been deeply integrated with patterns of design architecture.

Several studies have adopted the two features in analyzing the strategy of architecture portfolio and the strategy of architecture positioning transfer such as in [3]-[6]. The method was also applied in architecture analysis for car industry and geopolitical economy. The Monozukuri Strategy has been used for the macro-level analysis. However, how to use the theory in increasing the "manufacturing competitiveness" of a specific firm is insufficiently researched. In particular, the research goal is not only just a conceptual strategy but also a measurable and implementable framework that manufacturing firm can use to increase its manufacturing competitiveness. Our study aims to offer such a framework.

Takahiro Togawa, Nguyen Huu Phuc and Shigeyuki Haruyama are with the Graduate School of Innovation & Technology Management, Yamaguchi University, Japan (e-mail: haruyama@yamaguchi-u.ac.jp).

Oke Oktavianty is with Department of Mechanical Engineering, Yamaguchi University, Japan and lecturer at Industrial Engineering Department, University of Brawijaya, Indonesia.

2.1: Country/Economy Profiles

Global Competitiveness Index
2016-2017 edition

Key Indicators, 2015

Source: International Monetary Fund; World Economic Outlook Database (April 2016)

Population (millions)	126.9	GDP per capita (US\$)	32485.5
GDP (US\$ billions)	4123.3	GDP (PPP) % world GDP	4.25

Performance overview

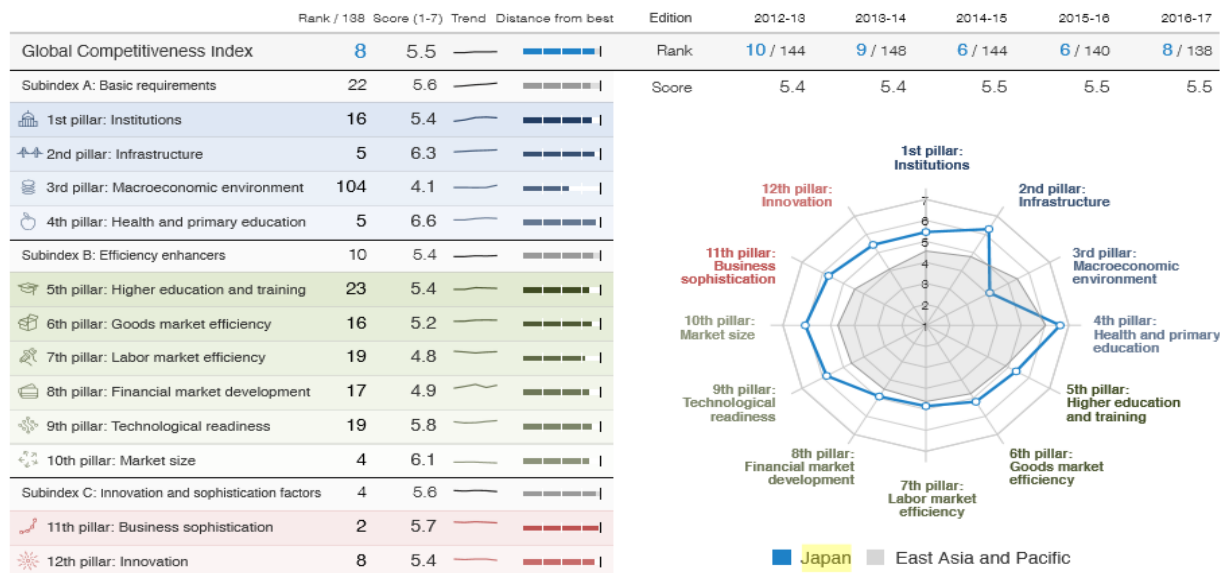


Fig. 1 Global Competitiveness Report in 2016 [1]

COMPETITIVENESS FACTORS

Government Efficiency					Business Efficiency					Infrastructure					
2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016	
57	59	60	61	58	50	54	57	58	55	46	53	53	51	51	Argentina
14	13	9	14	14	13	17	16	17	17	19	20	18	19	18	Australia
33	37	36	39	35	20	22	20	28	22	16	17	16	20	12	Austria
41	39	43	33	28	29	28	26	22	19	21	18	22	17	13	Belgium
55	58	58	60	61	27	37	46	51	51	45	50	52	53	46	Brazil
44	47	44	49	33	59	59	60	60	54	52	51	49	49	47	Bulgaria
9	9	8	8	10	9	7	10	3	12	6	6	6	6	9	Canada
17	16	21	26	27	21	30	30	35	36	42	46	47	44	45	Chile
1	2	2	1	1	1	2	3	1	1	18	21	21	15	21	China Hong Kong
34	41	34	35	51	32	25	28	27	26	29	26	26	25	25	China Mainland
50	42	49	51	53	48	44	48	41	45	57	55	56	54	56	Colombia
54	54	54	56	56	58	60	59	61	61	41	42	41	43	43	Croatia
30	36	38	31	29	41	40	40	31	30	30	29	28	28	26	Czech Republic
11	11	11	10	8	15	11	11	8	6	4	4	3	3	2	Denmark
24	30	23	20	20	38	39	32	36	34	32	32	30	32	33	Estonia
12	12	13	17	21	16	20	13	19	21	5	5	5	5	5	Finland
47	44	50	50	52	45	42	37	39	37	14	8	9	12	15	France
19	19	16	18	19	17	15	9	16	15	7	7	8	9	10	Germany
58	56	57	57	59	56	47	54	43	57	34	35	39	35	38	Greece
51	52	53	54	54	49	55	56	57	56	35	38	37	39	39	Hungary
38	35	27	22	17	31	36	31	29	27	10	14	13	11	17	Iceland
42	46	47	47	47	24	32	34	33	31	53	54	57	58	58	India
28	26	25	30	32	35	31	22	34	39	56	56	54	56	57	Indonesia
20	17	14	15	13	10	13	4	13	2	22	22	20	24	23	Ireland
21	21	24	24	22	18	24	21	21	23	13	13	15	14	14	Israel
49	55	55	53	50	44	46	45	44	35	28	30	33	31	32	Italy
48	45	42	42	37	33	21	19	25	29	17	10	7	13	11	Japan
31	40	31	32	44	51	52	47	47	40	47	52	50	50	52	Jordan

Fig. 2 Global competitive factor by IMDWCC [2]

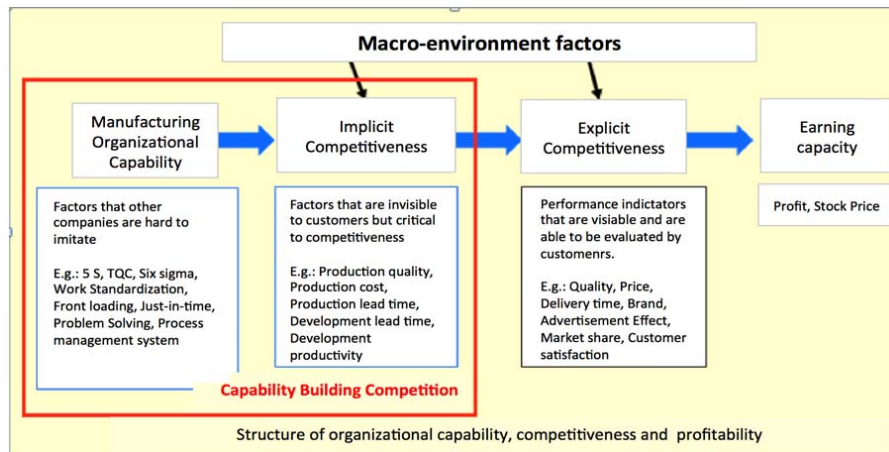


Fig. 3 Structure of Manufacturing Strategy Theory [5]

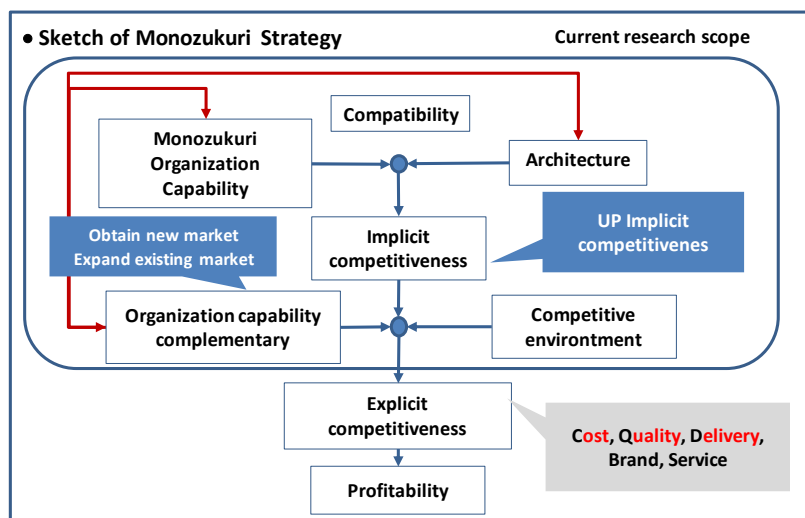


Fig. 4 Monozukuri strategy theory diagram [12]

II. RESEARCH METHODS

Fig. 5 shows the IPO (Input Process Output) diagram of Monozukuri Strategy theory. By analyzing and examining both the manufacturing organizational capability and its relevant production architecture, we can improve the implicit competitiveness. On the other hand, analyzing and examining both the manufacturing organizational capability complementary and its relevant production architecture can facilitate to process of finding possible solutions to acquiring new market and developing new technology.

As the implicit competitiveness and monozukuri organizational capability are closely related, the improvement of monozukuri organizational capability based on architecture will lead to improvement in the implicit competitiveness. Therefore, we can examine this effect through the process innovation. In addition, organizational capability complementary is studied in order to facilitate the development of new markets and new technologies based on the architecture. Therefore, the product innovation will be examined.

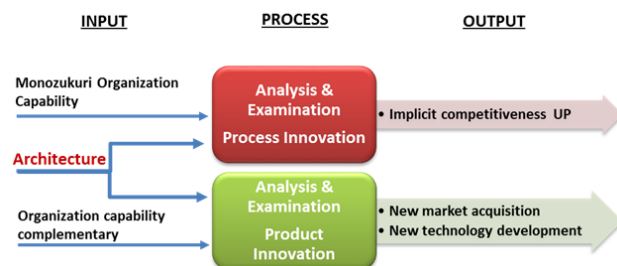


Fig. 5 Theory of Monozukuri Strategy Interrelation

The framework for analyzing the improvements of the implicit competitiveness in the process innovation is as follows:

A. Architecture Analysis

Analyzing the architecture will help evaluate the nature of the interdependency among the systems included in the product. Furthermore, through analyzing product / process

architecture and customer product architecture, we will be able to understand the characteristics of our products.

B. Survey and Analysis of Manufacturing Organizational Capability

Monozukuri organizational capability is unique to each company. Therefore, in order to understand the strengths and weaknesses of a company's monozukuri organizational capability, we will conduct an analysis on items based on 4M + R & D. Although these evaluation indicators can be used in analyzing the company's strengths and weaknesses, they are not compatible in comparison with other companies.

C. Compatibility Analysis

Manufacturing organization capability and product architecture are reconcilable. For example, integrated monozukuri organizational capability is compatible with integration architecture. Internal analysis (VRIO analysis, value chain analysis) can be used to check the compatibility between the manufacturing organizational capability and the product architecture.

D. Analysis of Implicit Competitiveness

QCD analysis will be conducted to evaluate the current situation of implicit competitiveness as well as its strengths and weaknesses.

E. Proposal to Improve Implicit Competitiveness

From the analysis results of A to D, proposals about the manufacturing organizational capability will be made to improve the implicit competitiveness.

III. RESULTS AND DISCUSSION

A. Architecture Analysis

Architecture is the philosophy of design. Architecture analysis is the analysis of products and process architecture to clarify the design concept.

In this section, we examine the nature of mutual dependency between systems included in products. The architecture classification table shown in Table I is used to classify types of architecture.

TABLE I
CLASSIFICATION TABLE OF ARCHITECTURES

	Product architecture	Process architecture
Integral / Modularity	Integral/Modular	Integral/Modular
Closed / Open Degree	Closed/Open	Closed/Open

1. Product Architect Analysis

The degree of integral architecture and the degree of open / closed degree need to be evaluated to classify the product architecture. The measurement is performed by dividing the number of end points of the function / structure connection line by the sum of the functional element and the structural element.

2. Analysis of the Degree of Openness and Closeness

The degree of openness/closeness is decided by the comparison with the degree of standardization in the related

industry. Therefore, the degree of openness/closeness depends on how standardized the interfaces and components are. Do they conform to industry standard, or company standards? The degree of openness is high if industry standards are used whereas the degree of closeness is high if the standard is exclusive.

More specifically, we evaluate the degree of exclusivity of the parts and the interface and judge the modularity degree by the exclusivity ratio in each part.

3. Process Architecture Analysis

The process architecture could be defined by applying the architecture concept to the production process. The process architecture is defined as the correspondence relationship between the production process system and the product structure system [6]. Therefore, the architecture is determined from the interrelation between product structure and the production process.

4. Degree Analysis of Open-Closed Process

The measurement of open / closed degree in manufacturing equipment will be conducted as a process architecture classification. The classification method is based on the exclusivity of the apparatus. The tendency of open / closed is obtained thorough finding the exclusive facility ratio for internal use and industry standard.

5. Customer Product Analysis (Product Architect)

The characteristic of the product will greatly influence the product architecture if the products are a part of a final product part. Therefore, the final product is divided on a functional component basis into several products whose each product's architecture will be analyzed. Analysis of the product architecture will be conducted in the same way as the one in process architect.

B. Literature Survey and Analysis of Manufacturing Organizational Capability

In the manufacturing strategy theory, the manufacturing organizational capability [9] is a prominent factor, particularly because of its effects on the next factor, the implicit competitiveness.

To examine the manufacturing capability, we adopted the framework called "4M + R&D" which is Man, Equipment (or Machine), Material, Management, and R&D. The manufacturing organizational capability will be evaluated through the five items in "4M + R&D" as follows:

- Identify the manufacturing organizational capability from the indicators of "QCD + F" and the "MAP".
- Conduct the "4M + R&D" analysis.
- Select the important factors from the QCD.
- Determine and investigate the evaluation methods and indicators. Although these evaluation indicators can be used in analyzing the company's strengths and weaknesses, they are not compatible in comparison with other companies [7], [8].
- Identification of manufacturing organizational capability: To determine the important evaluation items of the

manufacturing organizational capability, 1) list the items using the viewpoint of QCD + F, 2) to list the items in the manufacturing organizational capability, 2) divide them into 5 groups of 4 M + R&D, and 3) judge the important evaluation items. Fig. 6 presents the elements of

manufacturing organizational capability that was identified from viewpoint of "QCD + F" composition diagram. Next step is the preparation of MAP factor that consists of Q (quality), C (cost), D (delivery date) and F (flexibility).

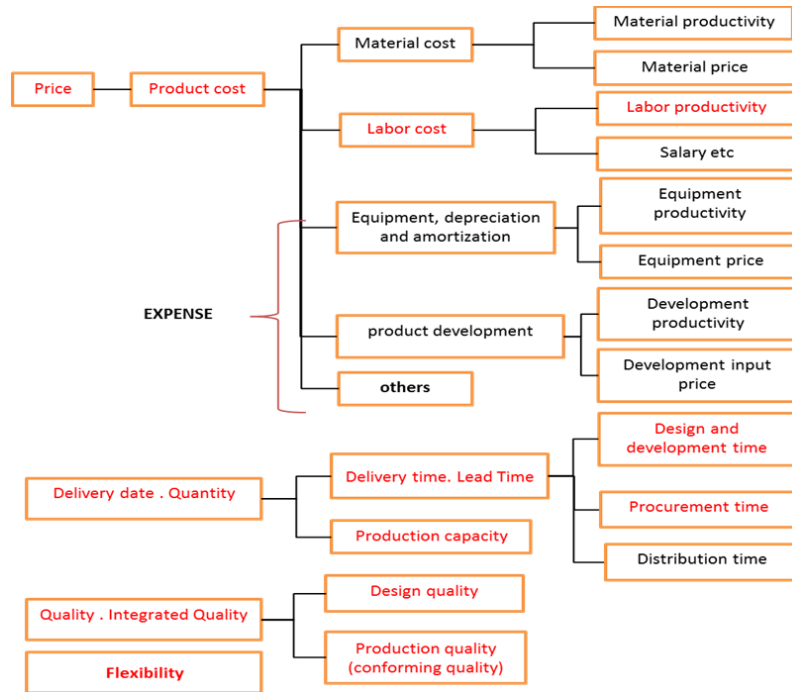


Fig. 6 QCD+F Diagram

- The QCD + F and MAP result are classified into 4M + R&D and decide the evaluation item as the manufacturing organizational capability. (The decision makers are the people with good knowledge in each related division).
- Examined and analyzed each item, e.g. the company's strengths, weaknesses, etc. The analysis result in this study is shown with radar chat in Fig. 7.

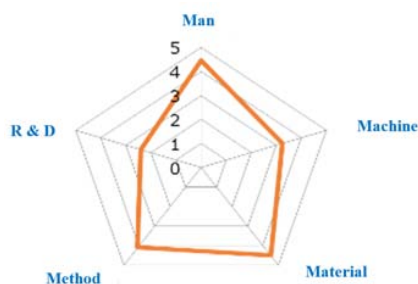


Fig. 7 Evaluation on manufacturing organizational capability

C. Compatibility Analysis

The compatibility between manufacturing organizational capability and architecture will be confirmed by value chain analysis and VRIO analysis.

According to [4] and [5], the compatibility of architecture and organizational capability, an integrated architecture (closed

integral type) will go along with “the capability to consolidate the entire system ex posteriorly”. Meanwhile, “capability to select system elements” or “capability to conceive system-wide rules in advance” will accord with modular architectures.

D. Analysis of the Implicit Competitiveness

The standard indicators of competitiveness in production and product development that cannot be observed directly by customers are QCD: Q (quality), C (cost), and D (delivery). Adding the additional indicator, "flexibility" to QCD, "QCD + F" diagram then can be viewed as competitiveness at the manufacturing site. The QCD diagram is defined as follows;

- Q (Quality): The design quality and production quality.
- The evaluation index of design quality is "quality yield", and the conforming quality is "the in-process defect rate".
- C (Cost): Product cost per unit of product. The product cost is assumed to be labor cost = labor productivity = net working hour ratio.
- D (Delivery time): refers to the procurement period = time from order placement to delivery (inclusive of product development time)

Delivery time is used as an evaluation indicator to evaluate design development time, production procurement time.

- F (Flexibility): The degree to which QCD is not negatively affected by changes in external factors such as changes in manufacturing environment and changes in diversity.

To strengthen the flexibility of manufacturing, however, we describe "3 M (man, machine, material) as enhancement of "flexibility" item. Since it does not appear directly in the numerical value, it is removed from the index.

The QCD's ability and challenges will be confirmed from quality yield, in-process yield, working hour ratio, development lead time, and production lead time, as shown in Fig. 8.

QCD	Item	Evaluation item	Index	Product	Comparison	Conclusion
C	Working hour	labor productivity	Common / general theory of work hour		-	A
D	Development lead time	Design and development period (panel characteristic improvement)				◎
D	Production lead time	Production period	Material procurement → shipment time			Δ
Q	yield	Design quality	Cusomer defect rate			◎
Q	In process - defect rate	Quality product	Improvement rate			O

Fig. 8 QCD Evaluation

E. Implicit Competitiveness Improvement

The manufacturing organizational capability that responds to the improvement of implicit competitiveness is clarified. The improvement not only has short-term effects but also constantly

contributes to increase the implicit competitiveness in the long term. Fig. 9 shows an example of improving the implicit competitiveness through manufacturing organizational capability.

4M	Reason for Implicit Competitiveness UP	Corresponding Organization Capability (4M)
Man	* Technical Competence (for automatic inspection) - Algorithm program training - Robotic introduction training	* Required new skill development Automatic inspection skill, robotic technology training Robot utilization training
Machine	* Low cost automation Simple robot technology * Test automation equipment	* Construction of Technology Robot technology * Automatic Inspection Technology New construction and development program of algorithm technology
Management		
Media		
R & D		

Fig. 9 Manufacturing organizational capability improves implicit competitiveness

From the analysis result, the relationship between manufacturing organizational capability with the implicit competitiveness is described in Fig. 10.

IV. CONCLUSION

In this study, we have discussed the analysis framework and procedures to improve the implicit competitiveness in the process innovation. The analysis procedure includes design/product architect analysis, analysis on manufacturing organizational capability, compatibility analysis, implicit competitiveness analysis using QCD, strengths and weakness analysis. To conclude, a final proposal to improve the implicit competitiveness has been presented.

Our research showed that there is a relationship between the manufacturing organizational capability and the implicit competitiveness. The analysis result also shows that it is necessary to improve the manufacturing organizational capability to optimize the implicit competitiveness.

The proposal for improving the implicit competitiveness will also serve for the long-term objective to constantly increase the

profitability. Hopefully, that will contribute to Japan's global competitiveness.

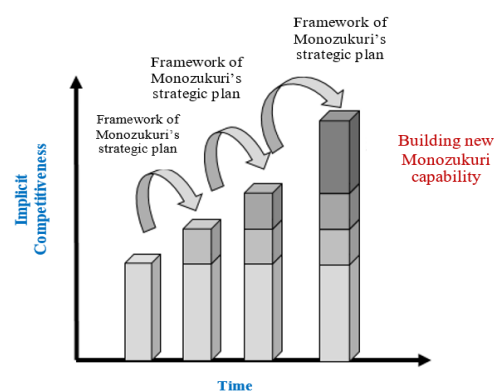


Fig. 10 Relationship between manufacturing organizational capability with the implicit competitiveness

The implementation of this framework will need to be customized for each company because of the differences in

their nature. Future challenge, therefore, is to verify the proposal by checking its results in different industries and companies.

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