Developing Effective Measures of Organizational Capability of Manufacturing Firms: An Exploratory Case Study of Japanese Manufacturing Firms

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Abstract: The present article explores the flow-oriented and routine-based concept of organizational capability in manufacturing and proposes a practical method of measuring it by using the flow map of material and information (FMMI), including the value stream map (VSM). The environment surrounding manufacturing companies is becoming increasingly turbulent, making it increasingly difficult for them to survive and prosper. For example, global companies face challenges on multiple fronts such as international trade tensions, pandemic lockdowns, and competitive challenges from firms in emerging economies. In addition, in digital markets, supply chain transparency and resiliency require visualizing the flow of materials and information across a wide range of global activities. Business activities are conceived as flows of design and control information from across functions for value creation and transfer. A high level of value creation is built on the excellence of vital function. In this context, this study aims to identify key characteristics of high-performance firms. In particular, the flow map of material and information (FMMI) assumes simultaneous execution of capability-building and capability-measuring. This research team reports the series of workshops and survey results based on (1) the work of the industry-university consortium, (2) the collaborative learning process through trust and information sharing among participating companies, (3) sharing improvement activities, and (4) identifying areas of poor flow (issues for each company). In addition, several selected case studies of Japanese firms highlight the impact of using FMMI for improving multiple performance outcomes and measuring their manufacturing capabilities at the same time. The lessons and implications are discussed.

Keywords: organizational capability; the flow map of material and information (FMMI); dynamic capability; industry-university consortium; mutual learning; measures of organizational capability; action research

1. Introduction

The purpose of the present paper is to explore the flow-oriented and routine-based concept of organizational capability in manufacturing and to propose a practical method of measuring it by using the flow map of material and information (FMMI), including the value stream map (VSM).

The recent market environment surrounding global manufacturing firms is increasingly turbulent and difficult. Their challenges are from multiple fronts such as international trade tensions, pandemic lockdowns, fierce competition with firms from emerging economies, increasing product complexity, and changing digital market expectations. With globalization, firms have moved their production base to different parts of the world. As
supply chains are stretched out far beyond domestic boundaries, visualizing the flow map of material and information (FMMI) is crucial for mitigating supply chain risk. The analysis of business activities focuses on value creation flow through cross-functional interfaces (e.g., new product development, production, purchase, and sales) [1]. This is to combine a plurality of various functions and activities that encompasses all entities and activities. The competitive battleground, therefore, lies in the way of designing, organizing, and managing these value flows.

What are the key characteristics of outstanding firms that achieve continuous growth and expansion despite the challenging market environment? In addition to managing tangible manufacturing activities, how do firms cooperate and coordinate various activities of the diverse internal functions (e.g., development, sales, purchasing, and logistics) and their entire upstream and downstream supply chain? What kind of countermeasures are effective for discovering and solving problems in the flow map of material and information (FMMI). In order to answer these questions, this study examines how firms develop organizational capabilities through their strategic process and implement them at the operational level.

Both strategic and supply chain excellence are important for value creation. In coping with various environmental challenges, a firm’s organizational capabilities include field-level competencies as well. The resource-based view and dynamic capability theory are useful in assessing the competitive capabilities of firms [1–5]. Organizational capability is the sum of all the added process values (i.e., a stable flow) and its management and production resources (i.e., company-specific stock). Organizational capability in manufacturing reflects the system of interconnected productive routines for competitive performance. For example, the Toyota Production System (TPS) is an example of organizational capability and its contribution is recognized in causal processes and performance relationships [1,5–11]. Toyota-style manufacturing, including TPS, has emphasized improving flows of value-added (i.e., flows of value-carrying design information) and thereby continuously achieving and enhancing productive competitive performance such as lead times, productivity, and quality [1,12,13]. This idea of continuously improving the flow of value-added subsequently inspired various management concepts such as the Lean Production System, Business Process Reengineering, and Theory of Constraints [11,14,15]. Each of these has had new aspects in addition to the original TPS, but what they all have in common was the concept of “flow”. In economics, it is a flow of value-added, while it is a flow of design information in Industrial Engineering and operations management, mainly because the design information of an artifact can be regarded as a source of value-added. However, it is not easy to measure the precise nature of organizational capability [4]. Performance outcomes are measured in terms of profit and growth, market share, product quality, productivity, and lead time. Even if a bundle of organizational routines is assumed to be a part of organizational capability, the actual measurement is very challenging. For example, Toyota’s production methods involve hundreds of organizational routines, but in practice, it is unclear to what extent each plant actually uses them.

Against this background, this paper revisits the flow-oriented concept of manufacturing, its capability-building, and its measurement. This paper explores the “flow-oriented concept of manufacturing (monozukuri)” that is regarded as the industrial activities of maintaining and improving “flows of value-carrying design information to the customers”; organizational capabilities that consistently maintain productive performances (i.e., the goodness of the flows including lead time, productivity, and quality); as well as the issue of measuring and improving such manufacturing capabilities. For firms and industries in today’s uncertain industrial world, it is essential to gain sustainable competitive advantages in terms of productivity, lead time, and quality (i.e., the flow’s effectiveness) in peacetime, while achieving supply chain resilience (i.e., the flow’s continuity) in emergencies such as natural/manmade disasters and pandemics [16–18]. In other words, building organizational capability to improve or continue the flow of value-carrying design information is a major challenge for companies and industries in the 2020s and thereafter.
This research team focuses on whether firms and workplaces that provide data for measuring organizational capability have the motivation or incentive to accurately measure their firm-specific organizational routines and provide them to researchers. Traditionally, the objectivity and validity of measurements have been strictly discussed [4]. However, in the case of data that are directly related to firm-specific competitive advantages, such as organizational capability, whether the economic entity to be measured has the motivation to measure accurately or not is considered to have a significant impact on the quality of the collected data. In this paper, we chose one of such definitions of organizational capability or a system of organizational routines that together consistently achieve stable and productive performance or goodness of value-carrying design information [19]. This definition suggests that manufacturing capability may be measured by counting the number or the fraction of organizational routines, each of which is expected to improve a certain "flow" in a certain part of the total manufacturing system.

For instance, TPS, according to its kaizen experts at Toyota, currently consists of more than 200 routines such as kanban, small lot production, levelization, one-piece transfer, autonamation, and 5S. Each of these is an organizational routine to improve the “flow” while systematizing them into a manufacturing capability. It creates fast, efficient, and accurate flows of value-added (i.e., good flows in terms of high delivery/cost/quality performances) for the entire manufacturing system. When Toyota’s kaizen experts initiate manufacturing improvements for a manufacturing site in other firms, they usually start with “capability diagnosis” in the target site by scoring what percentage of the routine group needed to improve the flow that is being performed. In other words, the measurement of organizational capability has already been carried out at the real site for the purpose of practical manufacturing improvement for years. In this paper, we suggest that we can academically refine this practical method of measuring manufacturing capability.

In this way, with regard to the aforementioned problem of the ambiguity of the definition of organizational capability, we argue that it is appropriate to adopt “organizational capability in manufacturing as a system of organizational routines that enhance the goodness of value-carrying design information to the customers” in accordance with the real practices in the Toyota-style manufacturing system.

We explore the methodological issue of the difficulty of accurately measuring organizational capability (i.e., a collection of organizational routines). Our idea here is to integrate the practical activity of helping practitioners improve their manufacturing capabilities and performances on the one hand and our academic efforts of measuring these practitioners’ manufacturing capability reasonably accurately on the other hand. By focusing on the concept of “manufacturing practitioners’ motivation to measure their routines accurately,” we argue here that the researchers of manufacturing management can improve their performance in measuring manufacturing capabilities by helping the target practitioners improve the flows of value-carrying design information. Accurate measures require management motivation to value the quality data of relevant processes. If firms recognize the value of organizational capability measures, they will make efforts to obtain and secure data with formal and statistical validity.

In recent years, with the wide availability of the internet, automatically measured behavioral data are available on a large scale (i.e., big data). To examine firm-specific competitive advantages, it is essential to obtain accurate data regarding key factors of organizational capability (e.g., organizational routines). The research team aims to study effective methods of obtaining accurate data on relevant factors of the organizational capability of Japanese manufacturing firms. As an important part of this research, we propose a new method called a flow map of material and information (FMMI). This is the result of collaboration between academic researchers and business practitioners through the projects of “simultaneous building and measuring organizational capability”.

Thus, the goals of this paper are: (i) to clarify the concept of manufacturing, (ii) to clarify the concept of manufacturing organizational capability, (iii) and to propose
solutions to the issue of measurement difficulty of manufacturing capability through the abovementioned systematic approach.

2. Literature Review

In this section, we survey the existing research on the concept and measurement of monozukuri. For the purpose of this study, monozukuri is defined as “the spirit and practices or organizational capabilities of Japanese manufacturing” [20].

2.1. Importance of Paying Attention to “Workflow” (Stream)

An essential purpose of a business firm is to contribute to society through the value transformation (i.e., input and output processes) for its target customers [21]. If this corporate view is applied to operations management, the key to work processes is the creation of value through a series of information flows across diverse functions (e.g., product development, purchase, production, distribution) [1]. No specific function is capable of completing this flow of value creation. In fact, the real value is realized by combining a plurality of various functions and activities across and beyond the firm. We consider that the real battleground is in this field of value creation flow.

Industry practices. The history of creative research is cumulative in that better studies build on previous achievements. Take the Toyota production method as an example. The commentary of Ohno (1988) on the “Toyota Production Method” recognized monozukuri (“flow work”) throughout the entire process of automobile manufacturing [13]. Toyota’s production method (i.e., lean production system) has been globally benchmarked, applied, and deployed in the manufacturing and service industries. The Theory of Constraints (TOC) explains how to identify the bottlenecks or constraints that stand in the way of achieving a goal and then systematically improve the process to remove or minimize its negative impacts [14,22]. Every complex system is connected through multiple linkage mechanisms and too often, the weakest link in the value flow often causes a huge disrupting effect on the entire process.

Academic research. An important job for managers is to manage the flow map of material and information (FMMI). Shimamoto (2015) summarized the historical research of Chandler (1977) from a flow management perspective. In order to manage large-scale and high-speed material flow, managers in the United States before World War II vertically integrated the multiple functions by devising a divisional structure in the form of a “visible hand” [23,24]. Firms that manage these multiple functional flows are recognized for their “organizational capability” [25,26]. In any case, a massively diverse flow map of material and information (FMMI) spans multiple activities and is thus very difficult to manage well.

In the field of strategy, Porter (1985) discussed the value chain and competitive advantage. A systematic examination of all activities and their interrelationships is necessary to understand the source of competitive advantage [27]. The idea of this value chain suggests that monozukuri (i.e., workflow) is crucial in measuring competitive advantage.

In the field of operations management, since the 1980s, an enormous amount of research work focused on studying the strengths of Japanese production systems (known as lean production systems) as a basis for comparing international production system performance [1,7,9,11,28].

In business history studies, the flow concept of production activities was applied to unit management in aircraft manufacturing [29,30]. In responding to customer needs, the Toyota Production System (TPS), or Toyota Production Method, was designed to achieve the overall optimization of the flow by applying innovative problem-solving and improvement activities. In addition, since the 1990s, the concept of a flow map of material and information (FMMI) was applied to examine cross-functional coordination processes (e.g., new product development) and integration of the entire supply chain. Empirical studies focused on how to achieve effective cross-functional workflows and the value streams of the supply chain for performance enhancements [31–33]. Although these studies were investigated from a value flow perspective, they did not dive into the details of the actual workflows of each
An effective examination of integration and coordination activities requires careful examination of the flow map of material and information (FMMI) across functions and supply chain value chain flows.

2.2. What Is the Organizational Capability of Japanese Manufacturing (i.e., Monozukuri)?

Monozukuri is about creating value-added through a competitive workflow for customers [1,3]. “Monozukuri” in a broad sense expects “good flow by good design” in the form of design information (i.e., information about the function and structure of artifacts and their relationships) and competitive outcomes (i.e., quality results, customer satisfaction, financial results).

Competitiveness might be measured in three ways: financial (e.g., profit performance), market (e.g., market share), and operational (e.g., productivity indicators) [1]. Competitiveness is ultimately about “the power to be selected and chosen”. Such criteria include firm reputation, product quality, and the work field level competence [1,16]. The normal indicator of “organizational capability” is a high and stable level of “good flow” of using the resources (stock of production resources) [34]. These are also conceived as a complementary bundle or a set of organizational routines [35]. In summary, organizational capability refers to the ability and power of an entity to utilize the given stock of resources for producing competitive outcomes in a stable and constant flow.

Organizational capability (i.e., monozukuri capability) is essential for the survival and prosperity of a company. It is unique to an individual firm or group of companies on a continuous basis of competitive outcomes [36]. It is embedded in the process of creation, translation, and transmission of value from design information and cross-functional processes to the customers. It is an intertwined systemic ability. It is utilized in daily activities. It is enhanced by the learning activities of the entire organization.

2.3. Static (Normal) and Dynamic Capabilities

Organizational capability of value creation includes: (1) static/ordinary capability that produces a high and stable flow of management resources, and (2) dynamic capability that applies rapid deployment of management resources [1,6,37]. Dynamic capability includes routine improvement ability and non-routine evolutionary ability [1]. Two patterns of value flows are noted here. The first is a static flow of value-added in a stable environment towards seeking high-level performance goals. The other one is a dynamic improvement of the flows in a changing environment for achieving either a continuous or discontinuous enhancement of performance [38].

There are at least three types of dynamic capability in this context: technology-developing capability, architecture-building capability, and capability-building capability [16,39]. Cohen and Levinthal (1990) emphasized technology-developing capability (as “absorptive capacity”) whereas Teece (2007) focused on architecture-building capability [40,41]. Fujimoto (1999) analyzed capability-building capability (i.e., evolutionary capability) in the automobile industry with a stable product architecture [1].

The Toyota method consists of hundreds of routines to create a “competitive flow” of value-added to the customer. For example, by the routine of “management of signboards (kanban)”, firms develop products that market values. They reduce the number of non-functional inventories, synchronize production lines, and engage in productivity improvement efforts. Managing organizational routines requires the creation of an overall “good flow of value-added” [1,12,13,42,43].

2.4. Challenges in an Empirical Analysis of Organizational Capability

Grant and Verona (2015) examined the practical challenges of conducting empirical studies on organizational capability [4]. First, there is a problem with the “measurement scale of organizational capability”. If responses are obtained by subjective evaluation, they only report what they know about their companies without adequate knowledge about other companies. Hence, the validity of a comparative study with such survey data
is relatively low. As a remedy, using fact information (i.e., objective data) is suggested. Second, there is a problem with the measures for approximating variables that cannot be directly observed as observables. The method of representing organizational capability through indicators such as the number of new product inputs and R&D investment might be considered. Then, the issue arises with construct validity. The third is the problem of a “black box” for measuring organizational capability. For example, in a cycle of “more experience-additional ability-bigger performance improvement”, the problem is that repetitive experiences may not enhance new required abilities. If so, performance might not be affected. On the other hand, in the case of qualitative empirical research, the key is how to classify organizational capability. Therefore, it is essential to set the research protocol accurately and clarify the criteria for the proper classification of organizational capabilities such as the reliable measures of performance of a specific task or function (e.g., key performance indicators), the subject’s perception (e.g., identity and purpose), and the observable behaviors (e.g., decision-making, activity, process). In any case, measuring organizational capability requires careful research design and measurement methods building on the findings and lessons from previous studies.

2.5. A Field Experience by Applying Toyota Production System (TPS)

For the on-site improvement activities of Toyota and other companies, the following steps were taken. First, a factory diagnosis is performed. The expert usually uses a checklist of organizational routines (for example, 100 items), observes “the flow of added value” in a form that reverses the flow from the shipping site, and points out where the flow is bad. As a result, this site makes a concrete evaluation of 70 points out of 100, and this becomes a trigger for on-site improvement activities or capacity building. Second is the measurement for a specific company. TPS experts perform the actual improvement activity in the form of using a flow diagram (e.g., value stream mapping) of task activities and information. It points out the places of “bad” flows and concentrates on improvement activity there. In this way, the complementary simultaneous execution of organizational capability building (capability-building) and organizational capability measurement (capability-measuring) is naturally performed in the field of real industrial competition.

2.6. Academic Research on Organizational Capability of Manufacturing Firms

What are the characteristics of a product creation company or organization that can provide high performance (e.g., quality, cost, delivery time, flexibility)? Empirical research on monozukuri (i.e., manufacturing-as-value-flow) activities, including product development, production, and purchasing, has progressed since the 1980s. Skinner (1969) paid attention to production activities as an important source of corporate competitiveness [44]. Hays and Wheelwright (1984) and Schonberger (1986) called companies that reported high performance as World-class Manufacturing or World-class Competitors [45,46]. After that, the characteristic was interpreted and conceptualized as a “Lean Production System” [3,10,11,33,47]. Studies on performance measures of monozukuri companies have also been conducted [48,49].

(1) “Lean Production System” in the automobile industry: HBS-IMVP study

Since the late 1970s, with the growth of Japanese companies and the plight of American manufacturing, researchers at Harvard or MIT engaged in research projects on automobile manufacturers [38,45,50]. Through the International Motor Vehicle Program (IMVP), the Toyota production method was specifically benchmarked, the concept of the “Lean Production System” was proposed, and the direction of performance research in production and development activities after the 1990s was decided [11].

After that, IMVP was conducted for multiple rounds, and in addition to production activities, detailed case studies and questionnaire surveys were conducted targeting development activities, support management, and even sales activities. In IMVP, performance is basically objective data (productivity, delivery, etc.) and organizational variable
diagrams (inter-departmental coordination, behavioral characteristics, and authority of product managers, etc.). Interviews were also conducted.

Even if it is limited to the automobile industry, there are differences in the complexity of the products among companies, and there is difficulty in correcting performance data [9]. The IMVP study had a great influence on subsequent research and suggested the concept of a Lean Production System or a heavyweight product manager [3,11]. By demonstrating that differences in countries and cultures do not produce differences in performance such as productivity, but differences in the management and strategy of development and production organizations produce differences in performance, the various characteristics that realize high performance are clearly identified.

(2) Cross-industry “best practices” survey: HPM study and IMSS study

Researchers at the University of Minnesota or Iowa State University at the time aimed to compare the North American factories of Japanese companies with those of North American companies [51–54], referring to the factors and variables that were mentioned by Hayes and Wheelwright (1984) [45,52]. As a result, the World-Class Manufacturing (WCM) project (later renamed the HPM (High-Performance Manufacturing) project) was started. In 1989, the first round was played for US plants only. The data were collected in the second round in 1996, the third round in 2005, and the fourth round from 2012 to 2013. From the beginning, Germany, Italy, Japan, and the United Kingdom were also included, and after 2000, Austria, Finland, Sweden, and Korea were also included, which developed into a cross-industry international comparative study. Although the relationship between coping and performance of JIT, TQM, and HRM in production activities is mainly analyzed, Bozarth, Warsing, Flynn, and Flynn (2009) analyzed supply chain management from the HPM project data [31,51–54].

In Europe, the London Business School in the UK and Chalmers University of Technology in Sweden are the center, targeting the manufacturing industry, and performing studies on performance, production strategy, and supply chain management through cross-industry while initiating the International Manufacturing Strategy Survey (IMSS) for international comparative analysis [55]. The IMSS survey was conducted in 1992 (600 companies in 20 countries), 1996 (703 companies in 26 countries), 2000 (558 companies in 23 countries), 2005 (709 companies in 23 stations), and 2009 (750 companies in 21 stations), and 2013 (843 companies in 19 countries). A total of six rounds have been conducted [56]. Various journal papers are published using IMSS data [32,57–63].

In the questionnaire survey of HPM surveys and IMSS surveys, a measurement scale was developed that enables comparative analysis of various characteristics of high-performance production systems beyond differences between products and industries. Subjective answers to questions about each practice or organizational approach were summarized, and the relationship between practices and performance was analyzed by identifying “leaness” in terms of the implementation level of the practice.

Researchers of HPM surveys and IMSS surveys, who have been measuring leaness in production activities from the 2000s to 2010s, are not limited to studies on production activities but a wide range of supply chains, and the skill of coordination and integration across functions such as production and development. The relationship between leaness and corporate performance is also studied [31–33,60,62–64].

(3) The relationship between the excellence of coordination and integration in the supply chain and performance

Empirical analysis has been actively carried out in the areas of operation management and supply chain management regarding the relationship between performance and the subtlety of coordination and integration across functions such as the entire supply chain and production and development. For example, an empirical study called “supply chain integration” is being conducted on the relationship between performance and the degree of cooperation and integration within and between companies [31,32,53]. In addition, empirical research called “cross-functional integration” is being conducted mainly on the relationship between the degree of integration among functions within a company and
its performance \cite{33,64,65}. The analysis method chosen for these studies is typically a questionnaire survey based on a subjective evaluation of the respondents on a 5-point (7-point) scale for questions about the degree of integration of information and activities inside and outside the company. After getting answers, the “leanness” of each company is measured, and comparison and quantitative analysis have been conducted between companies \cite{6}. The basic relationship that was revealed in the above study on supply chain integration and cross-functional integration is that if the flow map of material and information (FMMI) in the supply chain or engineering chain is good, the performance will increase \cite{6,28}. Therefore, the important issue is how to realize the integration and coordination between each function and company in the entire value chain.

As seen from (1) to (3) above, as a study to empirically elucidate the characteristics of an organization that realizes high performance, there is a study that analyzes the relationship between the characteristics of a production system and performance (1) targeting a single industry and (2) cross-industry or international cross-industry \cite{6}. In particular, in the latter case, cross-industry and international comparative empirical analyses have been carried out on the relationship between leanness and performance, which is the degree of implementation of best practices that are supposed to achieve high performance \cite{6}.

In these studies, key themes and questions that were explored were: (1) building value chain flows: “how to build a “good flow of things and information” related to a series of activities that constitute the value chain, such as development, production, procurement, and sales; and (2) the implementation of best practices \cite{6,28}. A devised questionnaire was created and empirical analysis was conducted to examine the degree of implementation of these practices and their impact on performance.

(4) The scale measuring leanness: Shah and Ward (2007)

Shah and Ward (2007) developed a quantitative and cross-industry questionnaire for measuring “leanness”, a characteristic of high-performance organizations, by organizing and integrating the measurement scales of HPM research and IMSS research \cite{10}. Shah and Ward (2007) reviewed the research on lean production and asserted that confusion and inconsistency about lean production still occur in the academic and practical worlds \cite{10}. Therefore, the main purpose of lean production is defined as “to reduce waste by reducing the gaps in supply-side, processing (working) time, and demand, and suppressing them to a minimum”. A total of 48 Lean-related practices were revealed from previous studies, and they were reduced to 41 practices by exploratory factor analysis (EFA) based on a pilot study. These were further reduced to 10 factors by confirmatory factor analysis (CFA). They argue that it is important to grasp the lean production system as a totality of multiple practices, showing meaningful positive correlations among these 10 factors. Shah and Ward (2007) summarized the relationship between ten concepts constituting lean production and actual measurement items. There were 10 items (more questions for each item) that were set as the constituent concept of lean production, and a 5-point scale was used for the degree of implementation of each practice in the factory (1 = not implemented at all, 3 = implemented to some extent, 5 = complete implementation). These 10 items are big and are divided into three categories: (1) situation in a factory, (2) supplier-related, and (3) customer-related. Shah and Ward (2007) also tried to develop a measure of lean production but did not analyze the relationship between measurement scales and performance \cite{6}. Furlan, Vinelli, and dal Pont (2011) expanded the survey items and measurement scales of the HPM project to the variables and scales of Shah and Ward (2007) using data from 2005 to 2007 \cite{10,66}. It analyzed the relationship between complementarity and performance among lean bundles.

(5) Value stream map (VSM) as the flow map of material and information (FMMI)

Value stream mapping (VSM) is “a lean management method that uses visualization, analysis and improvement of all the steps in a product delivery process” \cite{28,67,68}. For Western companies, the value flow of the company’s production system reflects a lean concept, but it is an application of the flow map of material and information (FMMI) diagram that is applied to TPS \cite{68}. By using VSM, Rother and Shook (1998) discovered a bottleneck that
was causing waste in the “current state map” of the supply chain (purchase, manufacturing, and sales) [68].

By advancing improvement activities by VSM, there were visible performance improvement effects (e.g., a reduction of the lead time in grain processing work). After that, a group of routines that are related to improvement and coaching in Toyota Motor Company is referred to as “KATA” [69]. Liker and Meier (2005) examined the value creation activities, identified the bottlenecks, and reduced waste work that was occurring in the entire value flow [42].

In recent years, VSM is regarded as an important tool for improving the flow of value. In Fukuzawa (2020), with the keyword search by “value stream map” (VSM), a total of 75 empirical research papers were noted [28]. In all of these empirical analyses, VSM is positioned as an important tool for realizing a lean production system. Fukuzawa (2020) shows that these empirical studies (1) visualize the flow map of material and information (FMMI) in the current production process, (2) discover the bottleneck in it, (3) draw a picture of the future, (4) implement a factory for improvement and draw a scenario for improvement, (5) define improvement effects in expected performance, and (6) combine simulation analysis and predictive analytics [28].

Accurately drawing VSMs of the target manufacturing, placing a set of manufacturing routines for improving each part of the total flows, identifying the “bad flow” area, making improvements there, and checking the “bad flow” of the company with other companies for the same part—the sequence of such activities may achieve manufacturing improvements for the practitioners and reasonably accurate measurements of their manufacturing capabilities at the same time [28].

2.7. Moving beyond Current Measurement Methods

(1) Limitations in quantitative research using subjective scales

Shah and Ward (2007) noted that large-scale, cross-industry surveys using questionnaires that were conducted in the 1990s and 2000s have analyzed the relationship between achievement and performance of practices constituting lean production systems [62]. The advantages of such a research method using subjective scales include: (1) cross-industry analysis based on common standards, (2) quantitative analysis of large-scale samples, (3) the leanness scale assesses the degree of performance achievement of each company and improvement needs, and (4) the publication of research results [6].

However, the following issues are noted with the existing measurement method. Other than abstract leanness state advance, the impact of “creation and utilization of design information” in each context is not necessarily well-captured [1]. Therefore, it is unclear how to identify the diversity of actual monozukuri activities in each site and assess the difference in the organizational capability to support these activities. If companies that do well in “lean practices” account for the majority of the responding companies, differentiating other firms that are not is becoming a research challenge.

To explore these issues further, members of this research team visited and investigated the development and production sites of automobile manufacturers in each country. Even in Japan, the research team visited the production sites of several automakers and observed and investigated the actual work activities of field workers using the original posture of the flow map of material and information (FMMI) in real contexts [6]. Specific questions in the field sites included: “does this site use a lean scale?”, “is JIT production actually applied?”, “are statistical quality controls measured used?”, “is there real work on preventive maintenance?”, and “how is the impact of company-wide quality improvement activities?”. As the question was on a 5-point scale, no company site responded with 5 in most of these questions. With a perfect score of 5 on a particular question (e.g., “We are carrying out very well.”), actual observation of the site and listening to the field workers showed different pictures. Although the idea of JIT production originated in Japan, the highest “JIT production” achievement of 5 points does not mean that their “lean scale” is excellent. Indicators of the leanness scale suggest their organizational capabilities and thus
outstanding performance results. This suggests that other organizational factors are not picked up with a lean scale in the same industry (e.g., automobiles) [6]. Cases of other industries might be somewhat similar. This is likely to be one of the “unaccounted” causes (i.e., 23% of the performance imbalance between factories) that was explained by Shah and Ward (2003) [6,10]. Therefore, it is necessary to devise a measurement method that may more precisely capture the difference in routines in each company, industry, or site. This may be an issue of the diversity of flow-oriented manufacturing or monozukuri.

3. Measurement Method of FMMI

3.1. Analysis of Units and Objects

The unit of analysis in this investigation is the field level (e.g., factory, development center, service facility). Starting with manufacturing, discovering problems is done by using a series of flow maps of material and information (FMMI) in the areas of production management, purchasing, product development, production technology, quality control, sales, and service management. In this way, the burden of the respondent is reduced as the reporting requirement is only about the actual “problem” site. Starting from the manufacturing department, the analysis efforts were extended to other departments that were located nearby.

The flow map of material and information (FMMI) may be used not only for time-series comparisons of the same site but also for cross-sectional comparisons of multiple sites with different performances. For example, a manufacturing firm may choose its higher-performing and lower-performing factories that produce similar products for its comparative FMMI studies, so that the company can gain various insights regarding the root causes of their performance differences. The respondent of such FMMI studies could be a business office manager, a factory manager, a manufacturing manager, a production technology manager, and a site manager. When the analysis data are collected with a plurality of respondents, there is a better chance to assure the accuracy of information.

3.2. Survey Table Composition of Measuring Monozukuri Organizational Capability

The method that is proposed in this study has the following characteristics: (1) the problem area of each company is shown in FMMI along with the “problem-solution matrices”, and (2) time-series comparison is constructed from three measurement processes. Figure 1 is this overall image in order sequence: (1) total shape of FMMI: visibility of problems, (2) time-series comparison, (3) visibility of solution matrices, and (4) a comparison of the solution routines. All of these are created in standard spreadsheet files (e.g., Microsoft’s Excel) and thus they are easy to use for many companies.

Figure 1. The overall image of FMMI analysis. Source: By research team.
In this process, under the concept of simultaneously carrying out on-site (genba) improvement and capability measurement, the FMMI diagram is used to spatially grasp the locations where the flow stays and where the problems occur. In addition, responses are obtained about the nature of each company’s problem, criteria for judgment, factors that caused the problem, and the analysis results.

Discovering tasks in the FMMI. In order to avoid individual bias, the research team was conscious of making a series of value-creation activities from design to sales the target of the analysis. Figure 2 shows the reference diagram of FMMI on the supply chain side (i.e., purchasing-production-shipping). On the upper side of the map (i.e., space-based flow diagram), the flows of control information link the activity timings of the suppliers/producers/customers. Materials, together with the value-adding design information, flow through a series of production processes (e.g., A, B, C, shipping). Each process has specific performance parameters. The actual performance results are summarized in the form of a lead time ladder (i.e., time-based flow diagram) which indicates the components of the production lead time, including value-receiving time (processing time), inventory time, transportation time, and waiting time.

In Figure 2, the square (box) indicates the productive resources (e.g., the stock of tools and equipment, human operators, and information embodied). For example, there are raw materials/parts (things), production instructions (information), and design BOM (information). Arrows indicate activities (flows), and it is assumed that there is a routine supporting this activity in the background. Both the flow of “materials-as media” and the flow of “value-carrying design information” are targets. For example, in the case of a company that purchases parts from overseas suppliers, as an activity such as “delivery of parts from suppliers”, “transport from overseas factories by ship once a week”, and after delivery inspection, it is expected that a reply such as “stored in stock location” will be obtained. Comparison uniformity is not easy for companies to answer because each has its own process, method of dispensing, name of a process, and individual technology and function. The flow map of material and information (FMMI) diagram is shown as a common reference map, and the “place number” indicates where activities are performed, for example, “M1” for “production instruction to each process”, and “M2” for “arrangement of manufacturing BOM to each process” from the development and production technology department to the manufacturing department, etc.). This map enables reasonably meaningful comparisons of the flow patterns, the flow-controlling capabilities, and the productive performance (i.e., goodness of the flow) between certain manufacturing sites of the same company/industry or the different ones.
It should be noted, however, that manufacturing sites in different types of industries may need different types of FMMI. Since the origin of the FMMI analysis is the automobile industry (e.g., Toyota), there may be a tacit assumption that the standard map is basically designed for the machinery (i.e., fabrication-assembly) industries. If such a standard format is used as the reference map for all industries, the participating firms in the process industries (e.g., chemical, steel, pharmaceutical), for instance, may find them difficult to apply directly. We may therefore need to prepare some types of industry-specific FMMIs in order to make all the participating firms comfortable when making their FMMIs.

At the same time, however, the basic layout of such FMMIs should be similar enough to each other, so that the participating firms (e.g., chemical producers) can learn efficiently from other participating firms of different sectors (e.g., automakers) by reading their FMMIs. For this purpose, the FMMIs for different industrial sectors should keep the minimum spatial commonality so that it is possible for all the participants to quickly identify the places in other firms where the flows are not streamlined or where they can be made better, and thereby make quick comparative flow analysis across different industrial sectors. Conversely, they can grasp their own unique processes, functions, and activities through such cross-industrial FMMI analyses.

When progressing through the process of showing tasks in the flow map of material and information (FMMI), the respondent is asked to fill out the task discovery and understanding sheet. Appropriately, both the researchers and the respondents can act together. The object to be answered is the department that looks at and connects the manufacturing sector, the production management sector, the development/production technology/quality sector, the purchasing sector, the sales sector, the service sector, and the whole flow.

4. Case Study

This study adopts an exploratory case study. The results of using our research methods are reported.

4.1. SystemCare: Shortening the Production Lead Time of X-ray Machines

SystemCare Inc. in Nagaoka produces an X-ray machine that tests foreign objects in packaged foods. The company has 23 sales offices nationwide and customizes the dimensions and measurement accuracy to meet customer specifications. The research team worked to shorten the production lead time in order to start up mass-production machines that customers can easily install. The company was a one-man assembly process, which took five days to assemble, but was eventually reduced to three days.

First, a comprehensive flow chart of everything from sales to design was created. There is a problem that comes from looking at the whole. The general flow chart of materials and information includes the flow chart of materials and information in the assembly process, the flow chart of materials and information in the outsourced sheet metal manufacturing process, and the flow chart of materials and information in the sales and design work. In the assembly process, the work of the assembly process and the wiring process were standardized. In the outsourced sheet metal manufacturing process, meetings were held with outsources based on the flow chart that was prepared.

Figure 3 shows the business process from inquiry information to order confirmation and design. The left side is the work before receiving an order, and the problems are as follows and are represented by jagged marks. The orders may be received from distributors, but information on design specifications is difficult to obtain. When an inquiry is received, the history of the order confirmation is not managed, which causes a problem in design. Since it is a food inspection, samples are always taken and the design is started based on the data of the sample test, the data management of the sample test is very important, but the sample data are not utilized.
In the production lead time map, the order confirmation is indicated by a triangle. The right side is the work after the order is confirmed, and the problems are as follows. Inquiries are frequent because design information through sales is unclear. At the manufacturing stage, the design change part cannot be understood. For the former, it was decided that the design department would create a standard format for grasping necessary design information. The company has invited sales representatives from 23 locations across the country to hold training sessions. For the latter, we created a mechanism to communicate the changes later. All of these things are normal, but the problems that had been carried out casually were brought to light, leading to company-wide activities.

In the production lead time map, the order confirmation is indicated by a triangle. The actual production lead time is from the time the order is confirmed to the start of specification design and detailed design, and the start of sheet metal working. The flow chart of things and information looks at the work in a planar view, while the production lead time map tracks the work in time and is used in combination. The relationship between the site and design and between the site and production management seems to be getting weaker in various companies.

4.2. Frontier: High-End Blind Production Train Diagram System: Lead Time Reduction

Frontier produces luxury wooden blinds for use in hotels and other facilities. The blinds vary in size and color depending on the building. However, it should be completed four days after receiving the order. It produces about 50 sets of blinds a day, and the theme is how to supply without delay. It was originally a factory that made small construction hardware. From there, big blinds were produced, and the factory had a very complicated layout.

In the production plan, three patterns (small, medium, and large) were made from the width and length of the blinds, and the average standard man-hours (this process should be performed in how many minutes) were determined. In the production process, it is important to connect a series of processes from cutting and drilling to comprehensive inspection which takes time.

4.3. Precision Machined Part Firm: Improving Production Lead Time

The production lead time of precision machined parts is shortened in the same way. Semiconductor-related products are manufactured in a high-mix, low-volume manner using general-purpose machines that process a variety of materials. We often talk about
examples of train services on the Tokaido Shinkansen line when people feel that it is difficult to improve the situation because there is no dedicated machine. It takes 3 h from Tokyo to Nagoya by Kodama, but 1 h 40 min by Nozomi. If the long process flows first and the short process is inserted in the gap, the whole flow will be improved.

The QA matrix is the basis of the TPS, and is a method to create quality in order to realize that “we cannot accept, make, or send defective products.” It is an activity to improve the constitution by establishing checkpoints to ensure quality along with the flow of the process, discovering the causes of defects, and creating quality. Figure 4 shows an example of a checkpoint that is used to launch a new product.

Figure 4. Quality assurance barriers.

First, display defective products in the first place for a month. Then, bring up defects that they think are wrong and hold a review meeting. At the review meeting, the person who caused the defect explains the situation, and the subcontractor participates as necessary to put the “why” into practice. People from the Quality Control Division also participate in the workshop and learn about processing techniques. They do this on a regular basis. In the QA matrix, the vertical axis is 4 M (i.e., man, machine, material, method) and the horizontal axis is a checkpoint. The problem is characterized by thinking from the back. That is, we go back and check how the inspection process was, how the mechanical process was, and whether there were any problems with the drawings. If you spend four or five hours trying to figure out all the factors that cause defects, you’ll have a better ability to make other products. In addition, the outside arrangement (preparation work) of the tool which made the tool magazine table is carried out, and the skill map table of the manufacturing skill is also made in order to inspect the problem of the human when there is a defect.

4.4. Assembly Plant of Construction Machinery with Crawler

This company produces construction equipment with crawlers. Construction equipment with crawlers is an important product when entering wetlands and forests. Although the engine is procured from the outside, it is manufactured by in-house design, and the current production capacity is three per day. We are aiming for four of them and eventually five.

First, the direction of concrete improvement to achieve the production of four units per day was described. Upon measuring the man-hours of each worker, the assembling
process is made into two series, and cells are divided into the first half and the second half organized. After creating the process flow, the actual arrangement is considered. As the car body flowed, there was a stagnation phenomenon in that the first process had surplus power and the second process had no surplus power. The position of the car body is decided and the place which requires the most man-hours is done by two teams of two people, and when it is finished, the extrusion is done. In the end, they made the arrangement and flow chart for the person to complete by putting rubber on the crawler. However, the signage sheet also showed that the team was short of one person to make it four members in two teams. It is necessary to quickly select and train the expert in the bottleneck process. The problem became very easy to understand, and we were able to do it with four people as soon as possible. Even if four people can do it, it will be difficult to coordinate the processes of a large product. There was a mutual aid zone there, which was to help with the next step if the previous step was done early.

In the process of DX, a system is being introduced to share completed production information with sales representatives. In fact, there are a lot of cars waiting to be shipped. As the sales force is strong, the products are delivered in the order in which the negotiations are decided, and there are a large number of finished products in the process. In the future, we would wish to change the order according to the shipment. To this end, the research team started monitoring the vehicle layout and production progress. Clicking on it will reveal the vehicle type, customer delivery date, custom design information, and quality information. It was to DX by calculating information on the site backward to production control and sales. It was also to make the sales department feel relieved when they see this and just keep the deadline.

5. Discussion and Contributions

Several steps of extracting the problem from the field confirmation are worth mentioning here.

- Extract and confirm the “problem” flow by observing the field,
- Create a flow chart of materials and information (e.g., the current state, signs of the current state)
- Examine the improvement plan from the “symptoms” sheet.
- Describe the “symptoms” to be improved,
- Investigate the site deeply and extract problems,
- Consider measures to improve the problems.
- Return to the flow chart of things and information,
- Paint a picture of what to aim for,
- Move on to a 3-month improvement implementation plan and continuous improvement activities. It is important to continue these activities patiently.

Before using the findings for generalization, it is necessary to mention the limitations of this study’s measurement method. The survey answers required substantial time and effort. Although there was an incentive to participate in this survey, future analysis methods need an improvement of the response flow. Despite this limitation, theoretical and several managerial implications are discussed here.

5.1. Theoretical Implication

The measurement method that was proposed in this paper emphasizes the importance of comparison between sites that are continuously evolving and the importance of research based on high-quality data.

First, the measurement method in this paper can identify the organizational capability of a “continuously evolving field”. Based on the responses that were obtained at the time of the investigation, the organizational capability of each company’s manufacturing site at a certain point in time can be grasped as a “snapshot.” Then the variety of the capabilities between the manufacturing sites of these companies can be comparatively analyzed. Meanwhile, the dynamic analysis of time-series differences in organizational
capabilities can be explained by linking these snapshots and making a "motion picture" that shows the evolution of the manufacturing site in question. In other words, it is possible to grasp changes in organizational capability (i.e., the evolution of the ordinary capability itself) and to correlate them with strategic and organizational variables (e.g., dynamic capabilities) that can explain such changes. Researchers could analyze how the genba (manufacturing sites) adapts itself to the factors that bring about various changes (e.g., changes in economic conditions, market changes, natural disasters, "COVID-19" pandemic, and advances in digital technology) by accumulating such data over many years.

Second, the flow map of material and information (FMMI) that was used in this paper is a method to identify where the flow is not good and thereby drive improvement activities. Our method grasps the location of the flow problem and the reason for the problem together with the practitioner’s perception and the actual flow situation in the field. In addition, it is possible to determine the temporal trend of problem-solving behavior. In this way, the strength of the measurement method of this paper is that it enables the temporal and spatial identification of problematic locations, cross-sectional comparison between the sites of different companies and industries, as well as dynamic comparisons for analyzing the firms’ capability-building processes. It is a characteristic of the method of this study to pick up the problem-related causal network of the answering company, which is difficult to capture only with data and trends revealed by so-called “process mining”. In this way, it is possible to construct a method for finding and solving problems “that make sense to the people in the field”. This is possible because we are getting answers through cooperation with practitioners who have extensive experience and knowledge about monozukuri activities. It will be possible to grasp, drive, and support continuous problem discovery and resolution activities by continuing measurement activities.

Third, when we actually use the flow maps of material and information (FMMI), it is easy to zoom in or zoom out the level of analysis (i.e., the scales of the maps) according to the purpose of the practical analysis of the value flows. For future micro-level analysis, various sensors and digital technologies may be used, and detailed real-time process data may be collected for the dynamic flow map of material and information (dynamic FMMI) as a digital twin of the actual flows like a motion picture, while real-time performance variables such as cost, quality, and data on value-added time, lead time, etc. may also be collected accordingly. By using such real-time (i.e., cyber-physical) operation data for each process, sequence analysis and “process mining” can be utilized to the pattern, categorize, and visualize the relationship between activities. If such information can be collected for a certain period of time and compared between sites, the flow map of material and information (FMMI) may be able to identify what kind of flow problems are occurring right now and when/how we should solve them by simulating of the future flows. Furthermore, it is expected that the site-specific predictions on (1) what kind of flow patterns are realized and (2) what levels of performance can be achieved accordingly can be verified based on high-quality microdata. Such analysis at the micro level and the tasks identified at the flow map of material and information (FMMI) level that was shown in this paper can be performed by synthesizing the knowledge that is accumulated by various causal analyses. In addition, if we perform macro-level qualitative/quantitative analyses, we may identify the relationship between the tag part, the category, and the response value by conducting an interview or questionnaire survey on antecedent variables such as strategic variables and organizational variables. In this way, the relationship between the data that are obtained and the pattern of occurrence of the problems, and the causal relationship with performance may also be found. It is also possible to develop analyses based on qualitative data and in combination with qualitative comparative analysis (fsQCA) [70].

Fourth, by linking the competing firms’ actual problem-solving activities and the academic capability-measuring, we may identify organizational routines and practices that directly affect their competitive performance. In the situation where competitive environments surrounding the companies are intense and unpredictable, the firms are highly motivated to recognize the problem that they are facing and to find and implement
effective countermeasures (solutions) to it, including new practices, and routines that streamline the value flows. If we focus on such critical routines that belong to such “problem occurrence and resolution action sets” for each company, measure the flow-based organizational capability based on these critical routines, and compare them between the companies, it will be easier for us academic researchers to identify and measure truly effective organizational capabilities that act on inter-site and inter-firm differences of competitive performance.

As existing studies indicate, even if inter-firm comparisons of manufacturing practices and routines are made properly, it may not be easy to detect a system of effective routines (i.e., organizational capability) that cause significant differences in competitiveness between the sites/companies. In other words, even if we accurately measure certain routines and practices and analyze them statistically, we may not be able to identify practically important causal relations regarding the organizational capabilities that significantly affect the inter-site or inter-firm differences in competitive performance.

In addition, when competitive environments are rapidly changing, we may have to constantly renew the set of effective routines/practices that consist of the organizational capability in question. The close connection between the competing firms’ real-time capability-building and the academic capability measurement may make such renewals of measurement scales easier.

From the awareness of the above problem and opportunities, we attempted a new approach to the measurement method that can assess capabilities and implement corporate improvement actions and capability-building actions simultaneously. The measurement method that was proposed in this paper may be unique in terms of: (1) sensitively detecting variations between sites/firms based on actual issues that arise regarding the flows of value; (2) awareness and recognition of the nature of the critical problem and its impact on the entire value flows (that is, extracting what was recognized as important for the context of each company as a problem); (3) verification of the excellence in flow-oriented operations and discoveries of the opposite; (4) comparison of organizational capabilities of different sites and companies by collecting relevant performance data; (5) detection of critical flow problems and deployment of necessary resources to solve them.

We chose a set of Japanese manufacturing firms as our research field, partly because capability-building and capability-renewal efforts for surviving the global/digital competitions have been intense there between the 1990s and 2010s. Many, if not all, of the Japanese companies’ domestic and overseas monozukuri sites, have overcome multiple crises, such as the global financial crisis, the Great East Japan Earthquake, international trade frictions, the “COVID-19” pandemic, and the supply chain disruption. In this situation, it is extremely important that document what has been happening now in Japanese and foreign companies and some solutions that can be shared among the companies that are participating in our research project, can be discussed and shared. The research method that is presented in this article can function as a platform to create a sympathetic cycle of discovering and following individual flow-streamlining solutions and continuously building flow-oriented capabilities. By using the measurement method in this study, academic research can provide a useful reference point and revise theories that are related to organizational capability and create an “excellent value flow”.

5.2. Managerial Implications

Practitioners may find this measurement method useful in several ways: (1) the establishment of a company-wide version of the flow map of material and information (FMMI), (2) recognition of stagnation points of the total “value flows” in the FMMIs of various scales, (3) inter-firm mutual organizational learning for improving their value flows, (4) the prevention of a “functional silo situation” by facilitating open dialogue among members of diverse functions and firms, and (5) construction of a platform to promote co-creation and evolution that transcends differences in expertise, power relationships, perceptions, orientation, and interests across departments, firms and beyond.
Academic researchers may also see the value of this measurement method by (1) rapid collection of highly accurate and relevant information about routine practices through high responses of the project participants, (2) timely access to a relevant and comparable dataset of organizational routines, (3) effective execution of empirical analysis of organizational capabilities by focusing on synchronous and flow-streamlining routines, and (4) better presentation of analysis results and implications to the genba/practitioner.

6. Conclusions

Although many existing studies focus on the “excellence aspects in the flow”, our focus is rather on the “bad points in the flow”. By examining the poor flow and bottlenecks in each company, it is more likely to identify the weakest link in the organizational capabilities of each company. By addressing the issues of poor flow and their causes, it is more effective in discovering areas of improvement and determining effective actions. This “evolution-oriented” measurement method is useful to both academic researchers and business leaders in achieving both improving the entire value flow and developing reliable measures of organizational capability. Methodologically, it is a kind of action research that is based on real-world cases. Lessons from each sample case provide practical insight for improving the value flow.

The proposed “new approach to measuring flow-oriented manufacturing organizational capability” in this paper uses three specific methods: (1) visualization of issues in the “flows of materials and design/control information” of each site/company, (2) visualization of a “problem-solution matrix”, and (3) time-series, inter-site and inter-firm comparison of flow-oriented manufacturing organizational capability. The following tools are used to collect information: (1) “reference chart” which shows an “overall picture of the flow of materials and information”, (2) “worksheet” that documents the “flow of materials and information”, and (3) “learning tool” that indicates the awareness and mutual learning. The response results help to analyze and identify trends and characteristics of organizational capability through various work routines.

Future studies may consider how to present a schematic diagram of the entire value flow, and other socio-technological factors that impact the drastic improvement of organizational capability. In turbulent market/competitive/geopolitical/natural environments, the firms’ organizational capabilities are crucial for firms to design and implement agile practices for supply chain resilience, sustainable competitive advantage, and so on. Thus, the issues of rapid organizational capability-building and capability-measuring will remain an important research theme for years to come.

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