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A Case Study in Social Manufacturing: From Social Manufacturing to Social Value Chain

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Abstract: A new manufacturing mode, called social manufacturing, has been developing widely, and employed in many enterprises across the business value chain in recent years. Faced with this increasing dynamic, both enterprises and customers have to be more aware of the potential opportunity and benefit to be derived from this new manufacturing mode. One benefit is more value-adding potential for both enterprises upstream and customers downstream across the business value chain, compared with the normal mode. This research extends the application of social manufacturing to the entire business value chain system to bring new opportunities and value-adding potential for enterprises. This paper proposes a social value chain system that applies the social manufacturing mode to the entire value chain and contributes to three areas: (1) a new way of thinking for enterprises to create new opportunities to add value throughout the value chain by employing the social manufacturing mode; (2) establishing the social value chain system for all participants/enterprises across the chain in order to gain a win–win situation for all participants; and (3) suggesting some idea of a suitable performance measurement to monitor and evaluate the proposed social value chain system.

Keywords: social manufacturing; social value chain system; value-adding; key supporting technologies; digital-driven technologies

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1. Introduction

Social manufacturing (SocialM) was first introduced as a "third industry revolution" in the Economist magazine in 2012 [1]. From then, through the efforts of some pioneers who have advocated the SocialM mode such as Wang et al., this new manufacturing mode has been developing along with the development of relevant technology [2–5]. The discussion on SocialM has been becoming a topic of great interest with the growth of the sharing economy and Internet-based and digital-driven technology [3–8]. In practice, the business model of enterprises has been changed compared with the normal mode due to the rapid development of Internet-based and digital-driven technology. For instance, one topical sourcing mechanism in manufacturing—crowd-sourcing—has been applied to some enterprises in order to provide the potential to share capacity and ability by means of Internet-based technology [9]. With this SocialM mode, it is possible to connect different enterprises and even customers across the business value chain to enable an effective collaboration among enterprises and customers to the meet the customers' requirements [6–10]. With the revolution in technology and business mode in the context SocialM, value-adding activities by operational processes are not only contributed to by upstream and intermediate enterprises (suppliers/manufacturers), but contributions from all participants, including downstream customers [10–14].

Regarding the mode of business operation, a business value chain (VC) is a supply demand network that may include multiple layers of participants who are linked to the chain by business, and which can add value for their downstream customers by means of business process or activity. The operational activity of participants must aim at adding value to the product/service by each of their focused business processes or activities. In the context of new manufacturing mode-SocialM, the value-adding mode can also be changed with the new manufacturing mode, or extend to a more value-adding opportunity. Figure 1 shows a normal business value chain of an enterprise, with the major business process across the order delivery chain. The enterprise needs to make value-adding to customer orders through the process of the value chain. Regarding the functional process with customer orders, the Association for Supply Chain Management (ASCM) [15] points out that the entire supply chain/value chain includes multiple enterprises across the chain, and the associated process is "the integrated process of plan, source, make, deliver, return, and enable spanning from the suppliers' supplier to the customers' customer". According to the above illustration, an entire value chain contains multiple participants: different levels' suppliers from upstream and different levels' customers downstream, and we call all of them participants. The participants can be linked by three major flows: materials, information, and cash (see Figure 2), among which the information flow includes internal and external flows. For the single product order delivery process, in the context of the normal VC shown in Figure 2, the material flow is a forward flow that is from the upstream suppliers (higher layer participants) moving to the downstream participant (except product returns). The cash flow is a reverse flow from downstream to upstream. The information flow should be both ways in the chain as the involved participants should communicate or share necessary information. The management of the value chain is mainly associated with the three flows.

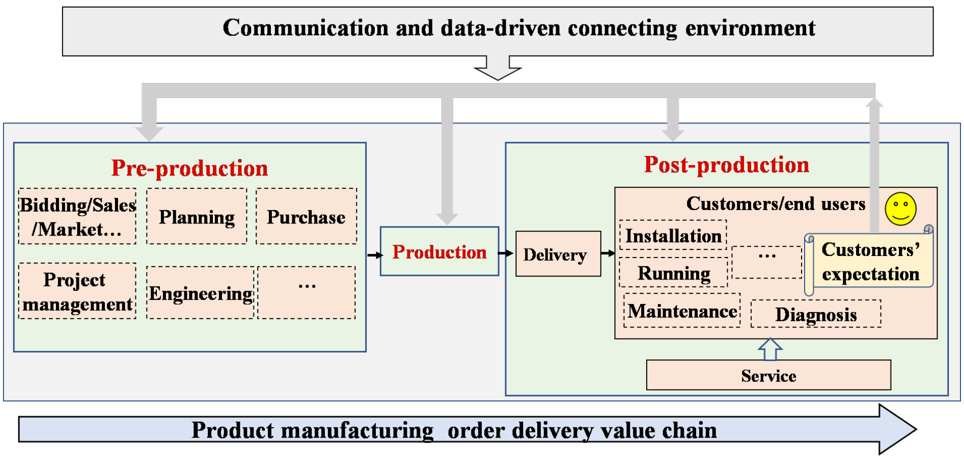

Figure 1. Manufacturing focused process for customer order delivery through the enterprise business value chain.

Figure 2 reflects the ASCM description, and the order delivery business VC consists of multiple participants across the chain, who are from upstream and intermediate (suppliers), to downstream participants and their end customers. In the normal value chain system, upstream participants need to create value (value-adding) to meet downstream participants' (enterprises and end customers/users) expectations; however, the customers make only a very limited contribution to the value-adding, except for providing the requirements or expectations associated with the order. In comparison, the SocialM mode offers more potential for downstream participants to be involved in value-adding activities across the value chain.

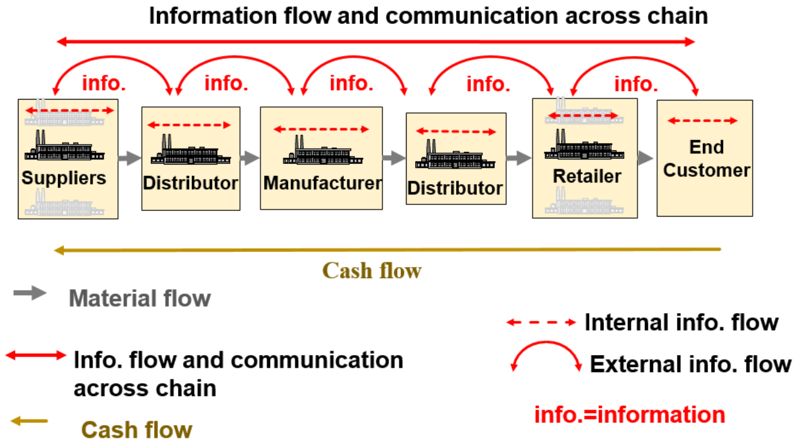

Figure 2. Three major flows through the value chain.

With the SocialM mode, new value-adding opportunities can be created by various socialized manufacturing resources (SMRs)/social manufacturing groups (SMGs)/prosumers (producer + consumer), including downstream participants and end customers who can connect and communicate through cross-enterprise-centered and Internet-based behaviors, supported by supporting technologies. Meanwhile, customers may obtain better quality, and better serviced product/service from upstream socialized suppliers/sub-suppliers. Upstream participants (socialized suppliers, socialized sub-suppliers) can gain stronger value-adding capacity to deliver product/service for their downstream participants (downstream suppliers and customers/users). In particular, cross-enterprise-centered suppliers can extend more value-adding processes, such as after-sales service to end customers/users or maintenance for the whole product lifecycle, such as remote service through a cloud-platform, or even establishing service-oriented manufacturing in the context of SocialM.

Before proceeding, we need to clarify two main types of value chains in business. The first follows the order delivery process from CO (customers' order) to delivery of the product/service to the customer. We call this a CO-focused value chain, as shown in Figure 2. The second type follows the process of different phases of the product–lifecycle (PL), which is developed originally from Stan Shih's smiling curve [16], and then extended to illustrate value-adding and sharing benefits in different phases through the entire lifecycle of the product (see Figure 3). This type is called a PL-based value chain. From a continuous improvement perspective, in a PL-focused VC, all processes/activities of phases from starting a product development to the end of the product lifecycle can be taken into consideration in terms of value-adding, and in the CO-focused value chain, all processes from customer demand to delivery of the product/service to the customer can be taken into consideration in value-adding. This research emphasizes the first type of VC: the CO-focused value chain.

In recent years, numbers of scholars have been showing great interest in the SocialM mode, its application, and supporting technologies. However, there has been relatively limited research on the potential of value-adding creation of SocialM spreading to the entire value chain, when compared with the amount of research attention to the manufacturing mode itself and supporting technologies. This paper takes the perspective of the entire value chain, and attempts to fill the research gap by presenting a case study in SocialM: a new perspective for adding value through the social value chain system.

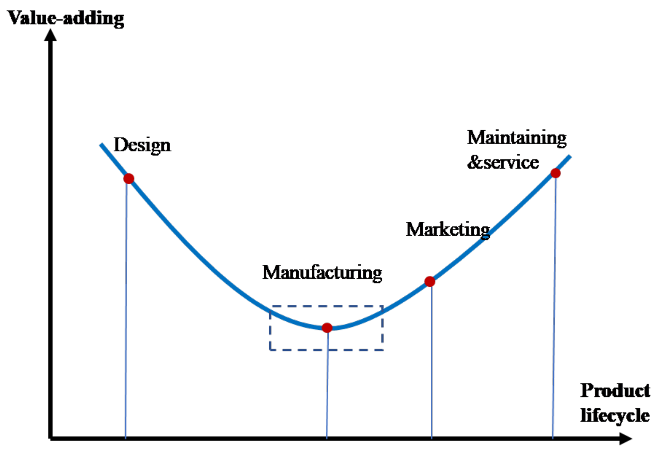

Figure 3. Smiling curve illustrating the relationship between the product life cycle and the benefits on different phases [16] .

The purpose of the current research is to propose a new perspective on adding value for enterprises and customers through applying SocialM. A SocialVC (social value chain) system is presented that extends from SocialM mode to the entire business value chain. The rest of the paper is organized as follows: first, a definition of terms, and literature review and prior work are presented. Next, the research method is presented and the results introduced, which present a new perspective on value-adding, establishing the proposed social value chain system with some relevant key supporting technologies (KSTs) and a preliminary idea for a high-level measurement model for the performance of SocialVC. Finally, a summary of the study and some areas for further research are presented.

2. Literature and Prior Work

2.1. Definition of Terms

To better understand the new perspective of adding value through the SocialVC system, it is necessary to give definitions of key terms in the SocialVC system.

Definition 1. ***Value*** *is defined from the customers' perspective (externally focused) according to Lean Thinking [17]. Regarding the SocialVC system in this paper, the true value extends to the prosumers' perspective in the product or service. Enterprises in the SocialVC system should consider a strategy to identify participants, including prosumers who will provide the required work in achieving value for the product or service in the future through the SocialVC system.*

Definition 2. ***Value-adding/value-added (VA)*** *is defined as an enterprise adding value to its products or services before delivering them to customers so that value in a product or service is a true value only if the customer is willing to pay for it. Enterprises in the SocialVC system can use the SocialM mode with KSTs for participants in achieving VA in growing businesses through the sharing of opinions, capabilities and capacity for "win–win" scenarios.*

Definition 3. ***SocialVC system*** *is the demand–supply chain between the end customer and the suppliers in the context of the SocialM mode. This system not only considers both high level information and material flow which cover all nodes (including end customer and key suppliers) as normal VC, but also applies SocialM to involved participants. The value-adding not only aims to deliver maximum value to the end customer, but also achieve win–win scenarios for all involved participants.*

Defining the system aims to fix the scope, products, and nodes that a demand–supply chain will cover. For this target, the effective method is discussion with the management to take overall business units and their activities into account.

Definition 4. ***SocialVC network*** *is a network of chains that produce multiple products or services for prosumers according to the SocialVC system.*

Definition 5. ***Node*** *is a point among key participants and the main physical process where goods/data/knowledge comes to stay or pass in the context of the SocialVC system. Key roles include prosumers and other participants such as SMRs and SMGs across SocialVC, and the main physical process includes warehouse, factory, and any connecting points between the key roles and other participants.*

Definition 6. ***Prosumer*** *takes the roles of both producer and consumer at the same time. The role involves a combination of consumption and production according to Ritzer et al. [18].*

Definition 7. ***SMRs*** *comprise all kinds of property-type and consumable-supply-type manufacturing resources that can be geographically distributed across the prosumers on SocialVC in order to provide the activities of SocialM for a product or service [13,14].*

Definition 8. ***SMGs*** *are manufacturing resources grouped together in the context of SocialM to input SMRs which provide participants across SocialVC. The SMGs can be categorized according to the participants' wishes, manufacturing interests, resources, and social activities in the context of SocialVC. In the SocialVC system, SMG provides SMRs for SocialM in order to create value for products or services.*

Definition 9. ***Crowdsourcing*** *is a mechanism to provide for a distributed problem-solving work on a product or service through an Internet-based tool, such as Apps, Internet-based social media, or other internet platform [19]. Crowdsourcing allows everyone to have a chance to be involved in the work or activities of relevant problem-solving if capable of doing so. The involvement can include offering work, information, or opinions which people can submit online.*

Definition 10. ***KSTs*** *is the technology that may be adopted to support the realization of the SocialVC system. Some examples of technologies include digital-driven technologies such as Internet-based technology, RFID, social sensor, CPSS, digital-twins, blockchain, big data, AI; supporting mechanisms such as crowdsourcing and outsourcing mechanisms; or methods such as modeling and simulation, supporting management to achieve various goals, continuous improvement (CI), performance evaluation, etc.*

2.2. Evolution of Value Chain Concept

The normal value chain was not a very new concept, when first introduced by Professor M.E. Porter, who first used this concept as a decision support tool to the competitive strategies of enterprises [20,21], who has completed the important pioneering works on the value chain to both business and scholars. According to Porter's value chain [18], the process could be divided into two types of activities in enterprises: one is primary activities that cover production, marketing, transportation, after-sale services, etc., and these activities are directly relevant to how value is created to a product or service. The other type is supporting activities that cover raw material supply, technology, human resources, financials, etc., and these activities can implement and coordinate the primary activities. In the middle of the 1980s, Hopkins and Wallerstein proposed a CC (commodity chain) concept [22]. Then, Gereffi further developed the theory of global commodity chains during the mid-1990s, and he introduced an analytical and normative usage to the value chain [23]. Griffin pointed out that multinational enterprises act as "drivers" which can play a role in governance in the global value chain (GVC) by organizing, coordinating and controlling international production and supply activities.

After the 1990s, GVC have experienced a transition from rapid expansion, upgrading to the transition process with occasional small contractions. The focus of some scholars has extended from a VC or GVC concept to improvement in efficiency and profitability by optimizing the value-adding mode through management or the business process [24].

Regarding value-adding from business to customers, the lean concept has been applied widely since the 1970s by enterprises to remove non-valued-added (waste) activities from the business process, especially the seven wastes that Ohno defined [25]. As described by Womack and Jones [26], five key lean principles are important for business: value, value stream, flow, pull, and perfection. Among these five principles, value is first defined for enterprises as the customer's need for a specific product or service. Since then, the five principles provide clear systematic steps for improvement in value adding that can be widely applied for continuous improvement in the business process of enterprises moving towards an optimized process.

Extending from the business process perspective to the entire business value chain, involved participants in the value chain should also consider effective ways for adding value across the VC. In past years, in the context of normal manufacturing mode, enterprises/participants in the VC have been putting effort into considering how value is added through their business process of manufacturing, e.g., value might be added from removing non-value-adding activities according to the optimization of overall value streams. Comprehensive thinking on the combination of value-adding from the lean concept and value-adding across enterprises from the VC concept provides enterprises with more opportunities to reduce non-value-added activities in the VC process [26–30].

Regarding improvement in value-adding, in the past years, there have been significant achievements in value-adding through CI (continuous improvement) in industry and service businesses [24,31]. For a long time, identifying and eliminating waste has been a major CI (continuous improvement) task for value-adding activities in the context of any value chain. Even so, many enterprises are still facing challenges that limit their value-adding capability in normal manufacturing or normal value chain modes. Especially since the COVID-19 pandemic, even more challenges have prompted enterprises to re-think what new perspectives on value-adding for both enterprises and customers would produce more advantages than the normal way. The new perspectives should mitigate the difficulty of adding value, moving towards satisfying customers' expectations and requirements for both enterprises and customers in the new situation [31].

The main issues in value-adding across the normal VC based on normal manufacturing mode are listed as below: - Role of customers: due to customers having their ideas along with increasingly customized and personalized demand for products and service, customer participation in the value-adding process upstream of the value chain is a trend in the product or service chain. For instance, in the garment and fashion industry, customer value can be better reflected if the customers' creativity is added in the design stage. However, the customer participation is very limited by means of a normal value chain.

- Sourcing issues: due to the limited capacity of sourcing in enterprises and the supply-side market, it is not easy to select qualified suppliers at reasonable cost. Therefore, waste is caused by sourcing or supplier issues.
- Service issues: due to service having been considered a crucial factor in competitiveness in recent years, many enterprises must try to meet the requirements from customers. In particular, for the process of after-sales, such as installing, commissioning and maintenance on-site, service problems have existed for a long time, and in the normal mode are difficult to solve. For instance, the crane industry has suffered from timeliness, effectiveness, efficiency in after-sales service, such as delays, and declining productivity [30]. In particular, with an increased amount of customization and personalization, the demand for after-sales service or product maintenance has been increasing dramatically. Good service can provide more value-adding potential for enterprises; however, most enterprises lack effective service systems or appropriate service providers and support technology to meet the requirements through the normal mode.
- Networking issues: from the perspective of connecting with customers, customer feedback is an integral part of the business. There is no scope for improvement if enterprises do not get to know what the customer likes and does not like. From the per-

spective of interacting and communicating among manufacturing resources, such as people-to-people, people-to-machine or machine-to-people, and machine-to-machine, the communicating and interacting mode has great room for improvement.

- Mass customization (MC) issues: due to customized and personalized demand in markets becoming permanent trend, there is a lot of space to create value relevant to customized products and services. However, regardless of mass production, lean production, or other normal manufacturing mode, it has been increasingly difficult to satisfy increased individual requirements and specifications by means of normal VC.
- Sharing issues: limited sharing of information on sourcing, capacity, and other resources among all participants in VC brings about huge waste through normal VC. For instance, enterprise A has excess capacity, while enterprise B in the same industry a lack of capacity, but enterprise B cannot utilize the excess capacity from A. Similar issues have widely existed in the context of normal manufacturing mode and VC
- Technical issues: lack of support technology limits the value-added capacity throughout the VC process Technical issues are also obstacles to the creating of value from enterprises to customers.

In order to solve the above issues, there is a need to explore different ways of adding value to solve issues that are not easily solved in the normal value chain. In particular, the uncertainties caused by the COVID-19 pandemic in recent years have not only ruined the smoothness of flows in the supply–demand network, but also further exacerbated the anxiety of enterprises. Our research proposes a new perspective of value-adding for enterprises/participants in the context of the proposed SocialVC extended from SocialM. The following review is about the evolution of SocialM mode to SocialVC system and its use in the participants' manufacturing.

2.3. Evolution of SocialM

The theory of SocialM mode has been growing and developing along with the concept of the sharing economy over the last decade [32–34]. At an early stage, the emergence of the idea of the sharing economy has opened up people's horizons and brought enterprises more opportunities or potentials [34,35]. One important opportunity was that enterprises could have more possibilities to add value as the boundaries of manufacturing capabilities were expanding, bringing about a change in the customers' role from buyer to "prosumer" [18]. This new role can create more possibilities to create value to the ordered product/service in the context of SocialM. The prosumer concept in SocialM extends the responsibilities of customers and users, which can bring more value to consumers (prosumers in SocialM), such as better products and more professional services [13].

Regarding business operations, the sharing concept has shown power when it is applied in service operations, well-known examples of which are Uber and Airbnb [34]. Meanwhile, some public social media that need digital content operations have been growing rapidly, such as businesses pioneering Internet-based technology: Facebook, Twitter, and WeChat, amongst others. The operating mode of these public social media have not only influenced people's daily communicating, but also changed social manners that people have been used to using. Consequently, the change of communicating and social manners have significantly influenced the business model and promoted the development of the SocialM mode [6–13,36,37].

The emergence of the SocialM mode has changed the game rules among large and small enterprises in the business value chain. According to Hamalainen and Karjalainen, and Jiang et al., more individuals have participated in product manufacturing activities due to the evolution of Internet-based technology and communicating behaviors [6–12]. Clearly, not only enterprises in the traditional sense are affected by this change, but also MSMEs (micro, small and medium-sized enterprises), and even individuals. Moreover, KSTs also show the important power. For example, crowdsourcing and crowdfunding mechanisms and some service or product maintenance supported by Internet-based technology/systems bring new value-adding opportunities through customer order value chains and product value chains throughout the product lifecycle, through different forms of cooperation, interacting, and communication [9–14].

In practice, some enterprises have attempted to implement SocialM to solve some issues that the normal mode does not easily solve in order to create more value-adding opportunities. Some enterprises have adopted digital content or coding operations to achieve benefits from applying the SocialM mode. For example, RepRap has used the open-source 3D printers' manufacturer network as a new model for product development, and it has been beneficial from relevance open design platforms based on SocialM mode [38]; Vehicle Forge platform has provided a virtual collaborative environment for design work by the cloud infrastructure [39,40].

While SocialM mode has been applied and made progress in business, the academic discussion has also kept pace with the technological progress and gradual in-depth application. According to Wang et al., early in the development of SocialM, it was defined as a new manufacturing concept and emphasized social computing and considered social intelligence techniques in the configuration of outsourcing and crowdsourcing for the whole product life cycle [2,3]. Shang and Xiong et al. thought that SocialM used the smart-interactive connection of dynamic information to process manufacturing services, instead of the whole product life cycle focus. In their opinion, SocialM can be considered as a production process that consumers could be fully involved in through the internet, and relevant equipment could be connected directly on the network by the smart-interactive terminal [4,5]. Later, with the development of Internet-based technology, Hamalainen, Nyberg and Karjalainen et al. defined SocialM as a new collaborative manufacturing mode in which the relevant process can be facilitated by mobile technology, new digital manufacturing, and online social networks. They emphasized the application of new supporting technologies and advanced manufacturing concepts, such as 3D printing technology, mobile technology, customization concept, value chain concept and social networks. [6,7]. This paper uses the definition introduced by Hamalainen, Nyberg and Karjalainen as our study focuses on the CO-focused delivery value chain, which corresponds to this definition. Jiang et al. took into account the key factor in SocialM illustration, and pointed out that "SocialM is defined as a kind of Internet-based and service-oriented advanced manufacturing mode covering the whole stages of a product life cycle" [12–14]. In this definition, two important points were highlighted. The first was from a technical point of view, which was Internet-based technology, and the second was a distinct service characteristic, which met requirements across the product life cycle. Jiang's definition corresponds to PL-focused VC.

To have an overall understanding, Jiang et al. summarize the seven characteristics of SocialM as below [14]:

- Microlization and minimalization of manufacturing resources;
- Self-enterprise of socialized manufacturing resources;
- Virus-like propagation of enterprise structure;
- Sharing and competing capabilities and business benefits;
- Dynamically distributive infrastructure;
- Big-data driven decision-making and performance optimization;
- Industrial software model to be used.

The characteristics summarized above are not only associated with and impact the manufacturing, but also deeply affect how to accomplish value-adding activities when compared with the normal business value chain. The SocialM mode breaks the normal organizational mode, sourcing mode and ways of interacting and communicating among participants in the value chain. These changes have not only brought about innovation in the manufacturing mode, but have also deeply affected the value-added mode that participants in the business value chain are involved in every day. The resulting new value-added mode with new business value mode has not only been an interest for scholars, but also enterprises seeking out innovative ways to satisfy their customers through the new perspective of value-adding. Many customers and suppliers/enterprises have suffered from broken supply chains caused by the COVID-19 pandemic since 2019, so the new perspective of value-adding through the innovative value chain mode has a deeper practical significance for enterprises and customers.

To make the application of SociaM possible, support from technology is very crucial, and this has attracted the interest of academic scholars. We categorize three streams of supporting technologies for SocialM. The first stream is digital-technology-oriented, such as IT, the Internet, etc., and we call this stream hard technology in this paper. The second stream is called people-oriented and includes management, organization structure, and the like. We call this stream soft technology in this paper. The third stream is social computing relevant technology that is combined with both hard (the first stream) and soft technology (the second stream), and constitutes an extended version of the SocialM mode to realize the Societies 5.0 [40,41].

Regarding the digital-technology-oriented stream, a number of digital technologies have been developed since NC (numerical control) first occurred in manufacturing, some of which could support SocialM according to the manufacturing requirements. In the early stage of SocialM applications, Internet-based technology provided more possibilities for SocialM application [2–13]. Among Internet-based technology, 3D printing systems were considered to be a key enabler in implementing SocialM [10–14]. Recent developments have been the Internet of Things (IoT), cyber-physical-systems (CPS), RFID, social sensors, loud computing, blockchain, big data, digital-twins, machine learning, and deep learning [4,11–13,42,43]. Among these technologies, the social sensor is important in data transfer and in interacting and communicating among enterprises and various manufacturing resources in the context of SocialM, such as between "people–machine–material", "people–people", "people–machine", and "machine–machine" [44]. The adoption of these technologies has accelerated and enabled the application of SocialM, such as cloud service [4], open product design [6,36,37,39], healthcare systems [44], the crane industry [45], amongst others. In the reality of manufacturing, the application of digital-oriented technology still requires effective cooperation between people, and organization structure and corporate culture, which is called people-oriented technology in this paper.

Regarding the people-oriented stream, people's behavior, the organization's structure, and way of communication and cooperation among participants across the value chain must meet the new manufacturing mode from the social perspective [14,46]. As the environment of SocialM is different from the generic manufacturing environment, a corresponding change is required in the VC process. Consequently, a series of adjustments are needed in terms of people's behavior accordingly [6,47]. Meanwhile, the process change also brings about an organizational change [48], such as new roles, new mechanisms and new functions being established. The role of prosumers also brings about a new force to manufacturing resources for value–value capacity; a crowdsourcing mechanism can be applied to connect prosumers with upstream suppliers or manufacturers in the VC [4,8,47,49]. Self-organization corresponds to a dynamic resource community (DRC) in SocialM in order to provide suitable capacity for production and product-driven services to prosumers [13,49,50]. Moreover, all people/organizations have to have skills that align with SocialM requirements and take on the relevant responsibilities through VC. In reality, the behaviors involved with connecting and communicating between people in the VC could draw on some social-media-like technology. It requires people to cooperate skillfully through relevant Internet-based technology, which belongs to the digital-technology-oriented stream. Therefore, the effective application of SocialM is supported by either digital-technology-oriented or people-oriented supporting technologies, both of which are associated with the third stream of SocialM supporting technologies.

Regarding the third stream of supporting technologies—social computing relevant technology—advanced supporting technologies can be effective in combination with providing a cutting-edge manufacturing solution in moving towards the Society 5.0 era, as Wang et al. has pointed out [40,51]. A number of supporting technologies have emerged, including hard and soft technology that provide more power to promote the application of SocialM. To do so, SocialM in practice will need not only a Cyber-Physical-Social-System

(CPSS) that is extended from CPS (Cyber-Physical-Systems) and provides a socialized ecosystem for SocialM, but also the SMRs that can provide numbers of self-organized participants/prosumers in the VC for various specialized product-related, production-related or service-related capabilities to meet customers' requirements [2,49–51]. In social computing relevant technology, more functions can be realized through a combination of different digital-driven technologies. For instance, social sensor and RFID could be integrated with CPS to form a CPSS platform in the context of SocialM, in order to provide the socialized ecosystem. Big data technology combining the technology of digital-twins/modeling and simulation can support the digitalization in SocialM operation [52,53]. Regarding the Societies 5.0 era supported by SocialM, a number of emerging technologies have been effectively combined and configured for different manufacturing scenarios to meet the customers' requirements in products/service. Among the many emerged KSTs, a parallel system method has opened up in the research on SocialM, as presented by Wang, which provide effective methods in the control and management of a complex system. According to Wang, one common system can consist of a reality system and one or more virtual systems that can have some artificial system [54]. Alongside this idea, one KST—digital twin technology—can provide a tool for modelling and simulation and analyzing SocialM application, such as product design, production line design, and even design for social factory [55–57]. For the decision-making of enterprises, big-data, cloud computing, combined with deep learning, can support performance monitoring in the VC and optimization performance if needed, as well as support decision-making [58,59]. In short, AI-based, Internet-based KSTs and appropriate organizational arrangement in the value chain can provide more configurable technology in the application of SocialM. According to research in past years, it is clear that more new technology is bound to emerge to enable SocialM application for various enterprises such as AI and digital technology which will continue to advance in the near future. In the following discussion, we will collectively refer to AI, IT, internet-based technologies, as digital-driven technologies.

As reviewed above, many scholars have focused on SocialM manufacturing itself and technology. This paper applies the SocialM mode to the entire value chain, in order to create more value-adding potential, which will also fill one research gap in relation to SocialM.

2.4. Contributions of the Research

To explore the possibility of solving issues that present obstacles to value-adding in the context of the normal VC, this research proposes a new concept: the SocialVC system that extends the SocialM mode to the entire value chain, towards creating more potential for adding value across the value chain. The main contributions are listed as below:

- New thinking for enterprises in terms of having more opportunities to add value, as compared with the normal manufacturing mode;
- Establishing the social value chain system for all participants/enterprises across the chain by means of the value chain concept and SocialM mode with supporting technology;
- Considering a suitable performance measurement to monitor and evaluate whether the SocialVC system works efficiently.

3. Method

A new sight must be opened to for all participants on VC to adopt the new perspective on value-adding by SocialVC that is associated with SocialM mode. In past years, many scholars have been interested in SocialM mode and its application in enterprises; however, a little research focus on value-adding across entire business value chain when SocialM mode is applied across business process of enterprise, this research will fill this gap. A methodology of the research begins with a context of the theoretical reviews on previous research both in value chain and SocialM subject, follows with new idea of value-adding from the proposed SocailVC in this research, ends up with a conclusion on an innovative way for enterprises to add value for both customers and enterprises in the context of SocialVC system that is a different way from the normal VC.

The methodology mainly outlines four parts in this paper. In first part, a systematic review on normal business value chain concept associated with this research is made. After that, a review of the SocialM mode is followed to describe the relevant work on the area of the SocialM mode. Based on these, a literature gap is identified in the area of analysis on value-adding, especially relevant to value-adding in the context of value chain for customer order delivery. In the second part, a new perspective of value-adding across value chain that extend from SocialM to an entire value chain is illustrated, and a new potential of value-adding is followed. The third part introduces some important supporting technologies to support value-adding in the context of the proposed SocialVC system. The fourth part explores possible measurement metrics to measure performances of SocialVC. In the end, some conclusion and suggestions on the future work are presented based on the above parts.

One reminder is that this work is an academic research, and the technology adopted to the relevant SocialVC system is based on current relevant supporting technologies, and the paper just discusses some major supporting technologies; łthere might be more existing technologies that are being adopted, but are not fully covered in paper or more innovative technology along with a continuing emergence of advanced technology may be applied for future SocialM or SocialVC, which is impossible to be covered in this research.

4. Results and Discussion

4.1. Establishing an Architecture of the SocialVC System

Regarding SocialVC system, it is associated with SocialM, the concept of value chain and the value-adding across chain, and some important supporting technologies mentioned in the previous sections. To establish the SocialVC system, this research proposes an architecture of the SocialVC system (See Figure 4). As Figure 4 shows, the architecture is layered and interconnected among each. The information and data through chain participants should be collected and shared by Internet-based social media platform, and the available manufacturing resources is identified. The required tasks for customer orders are distributed by means of supporting technologies. Meanwhile, SMRs are defined and matched to the SocialVC network. Finally, the ordered product/service and tasks are completed, and delivered by means of distributed SMRs/SMGs/prosumers. According to the above logic, the proposed architecture system is divided to five layers that are associated with the value-adding through the customer order delivery process in the context of the SocialVC system. The details of each layer are illustrated in the following subsections.

4.1.1. Layer1—Input Layer

Layer1 collects important data and information as input, which will be used for decision-making about the distributing of a resource with the required work. As Figure 4 shows, all input is from involved participants. Firstly, the involved multiple participants of each node on the VC is listed in layer1, and important resources of each participant are identified and collected, which should be sent to layer2—the support layer. In this research, we classify participants in three categories according to the manufacturing reality, namely enterprises, MSMEs (micro and-small-scale manufacturing enterprises)/Micro-enterprise [60] and individuals. Compared with the normal manufacturing mode and normal VC system, MSMEs and individuals have more opportunities to be involved more in the business to create value. Meanwhile, all participants can develop more flexible ways to be involved in the process of customer order fulfillment than in the normal value chain system, when these participants with relevant resources are included in the SMRs.

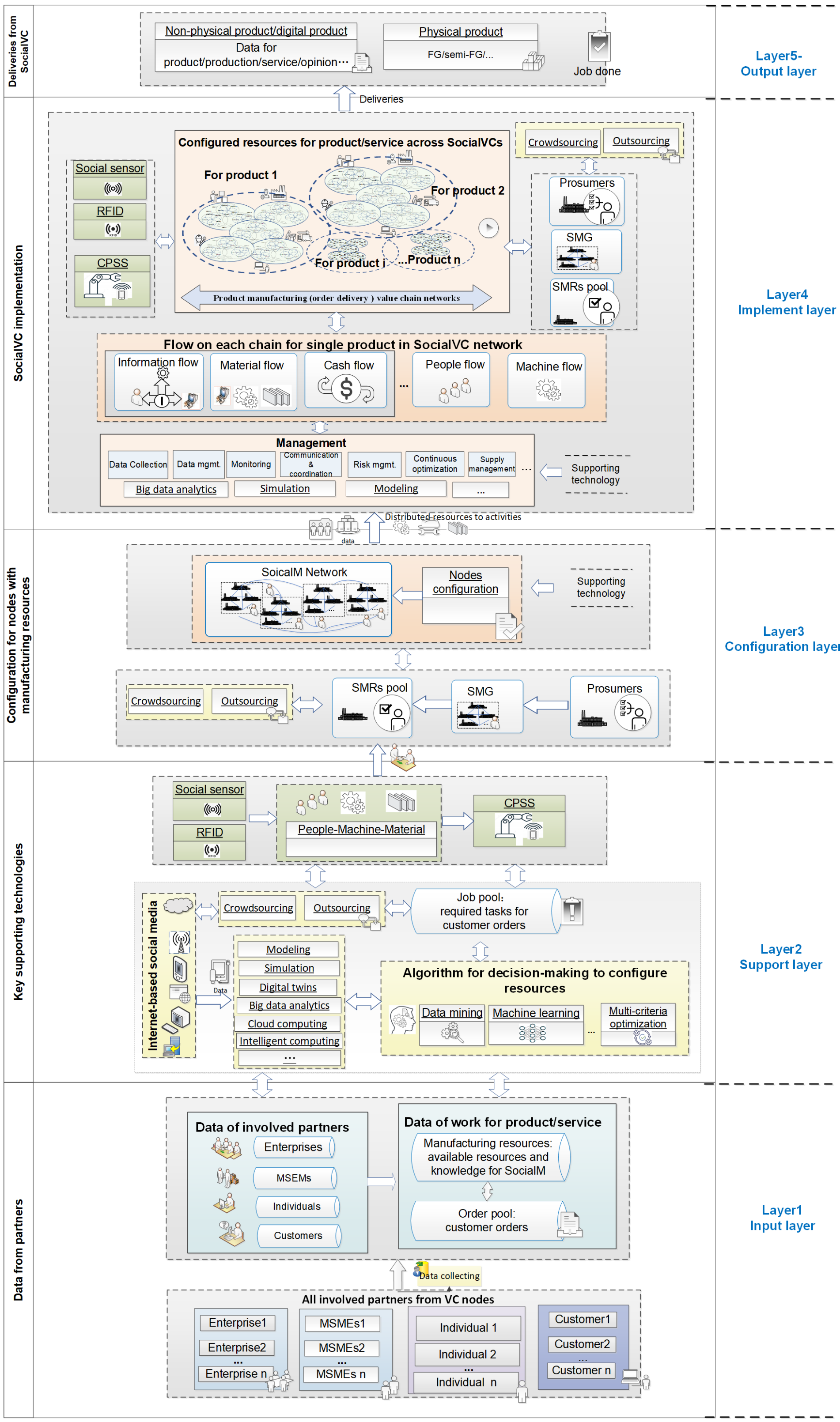

Figure 4. Architecture of the SocialVC system.

There are two main groups of data for input defined here. One group of data are manufacturing resources-related, including the available physical resources, nonphysical information, and knowledge. The collected data from each node/participant are a basis that present participants with the capacity to meet the required tasks that add value to product/service.

For the manufacturing business, the main resources can be classified as tangible and intangible resources. Tangible resources include resources such as the geographical sites, physical plants, available facilities, warehouse, local service or sales office, manpower, etc. These tangible resources can be adopted for value-adding activities through the manufacturing process in the value chain. Intangible resources include resources such as IP (intellectual property), brand value, trademark, self-developed software, knowledge and corporation culture. Intangible resources not only show competitiveness and advantages of the enterprise and power to create customer value, but also shareholder/stakeholder value. Besides data on resources, other important data such as key parameters also need to be collected, for example operations and supply chain KPI (key performance indictors) figures.

The second group of data are from customer orders for expected products/services. Due to the variability of the ordered product/service, the order fulfillment process varies widely, and relevant data and information need to be collected into a defined database system. All data/information are connected to layer2 through an Internet-based social media system and advance intelligent algorithm for configuration on SMRs. Participants become prosumers in the context of the SocialVC system, and they should be allocated to tasks of order fulfillment that are called task orders.

4.1.2. Layer2—Support Layer

Layer2 provides some KSTs which are mostly based on digital-driven technology to support the application of the SocialVC system. In the SocialVc system, each layer needs certain supporting technology to enable the defined function to satisfy the customers' requirements. The KSTs in layer2 not only support the manufacturing resource allocation for the manufacturing tasks in layer3, but also support the functions of all the other layers. The main KSTs include Internet-based social media, big data analytics, digital twins or modeling and simulation, and cloud computing. In addition, an algorithm to support intelligent decision-making is also important, containing big-data-driven data mining, machine learning, and multi-criteria optimization.

Through an Internet-based social media platform, the information and data can be transferred or even shared appropriately. Moreover, interactions and communication among nodes/participants can be performed through a social media platform, and behaviors of business process can be monitored and follow-up actions also communicated.

With support from the combination of social sensors and RFID, with CCPS, an intelligent configuration of nodes and SMRs for SocialVC is made and encapsulated. In particular, CCPS can also be widely adopted for effective interconnection and management among "people–machine–material" resources in multiple levels of manufacturing resources on the participants' site, including levels of machine, production line, shopfloor, and participants, involving for example the sharing and transferring of data and knowledge, dynamic scheduling, collaborating, and matching [12,50].

Through an advanced algorithm that integrates the data mining, machine/deep learning, and multi-criteria optimization, big-data-driven intelligent decision-making not only helps to identify and separate the customers' requirements into actionable job/activity, but also mines various relations and interactions among various resources, including SMRs and prosumers. The advanced algorithm also carries out configuration (configure layer) of the participants' resources by identifying the quantified SMRs with support from outsourcing and crowdsourcing mechanisms through SocialVC. All the capacity of configured SMRs needs to be distributed from the SMR pool to matched nodes (SMGs/prosumers) which will accomplish the required manufacturing tasks/task orders; hence, relevant SMRs/SMGs/prosumers will add value to the customer order through the business process in the context of SocialVC.

Through outsourcing and crowdsourcing mechanisms in Internet-based social media, more flexible capacity for production or problem-solving in value-adding activities can be gained in a competitive environment. The manufacturing capacity from outsourcing and crowdsourcing mechanisms is becoming one kind of socialized capacity, which not only creates value, but also may reduce manufacturing costs compared with corresponding activities/tasks in the context of normal manufacturing mode or normal value chain. Therefore, this type of outsourcing and crowdsourcing is also one type of value-adding mechanism.

Besides KSTs, there could be other manufacturing functions through the SocialM process, which are not included here. For instance, blockchain technology can be adopted as a credit and security mechanism, and 3D printing plays an important role in promoting decentralized social manufacturing [61,62]. 3D printing applied in SocialM not only achieves big cost savings, but also offers more potential for outsourcing, crowdsourcing and crowdfund mechanisms and the participation of MSEMs and individuals. In this research, we only focus on the more common KSTs relevant to establishing layers of SocialVC.

4.1.3. Layer3—Configuration Layer

Layer3 focuses on distributing manufacturing resources for the nodes/participants of each value chain in the SocialVC network. Various products are derived from various chains, which form the SocialVC network. Nodes on participants need to be distributed SMRs that match the required tasks in the job pool from the customer orders.

By supporting technically, the relations and interactions between participants in the value chain are mined and identified, in order to match SMRs from the SMR pool and required capacities of the relevant algorithm in support layer2.

From the operations prospective, the dynamic operation of outsourcing and crowdsourcing mechanism continuously collects updated information of manufacturing resources from prosumers, then matches them with the required tasks in the job pool. Finally, the task order can be made according to the successful match. During operation, the prosumers provide SMRs to SMGs, whose role is acting as an "agent" of various prosumers and works like a provider to the SMR pool. SMRs are made up of various types of enterprises, including big/normal sized enterprises, MSEMs, or even individuals. Meanwhile, as SMRs are characterized by socialization, decentralization, self-organization and specialization, they have the ability to provide the appropriate manufacturing resource accordingly [46], including tangible and intangible resources.

As various SMGs are grouped by similar business interests and common social activities, and provide various dynamic production capability to SMR, so numerous SMRs provide the configured capacity to nodes of participants along the chain. The task orders are performed by the configured capacity in SMGs, and relevant value-adding activities are reflected in products across the corresponding value chain. For instance, some enterprises with CNC (computer numerical control) as the main equipment can form an SMG, in order to take the kinds of task orders that need CNC.

All configured manufacturing resources are distributed to relevant nodes within the SocialVC network so that the prosumer on the node will complete the task orders or customer orders by means of the allocated capacity.

4.1.4. Layer4—Implement Layer

Layer4 is for implementing the customers' orders including all task orders or from the job pool in layer2, through configured SMRs in Social VC. The configured SMRs provided from the SMRs pool come from various different SMGs and are formed by prosumers. In order to fulfill an order, the configured resources are connected by process and supported by a defined management system for various goals.

Flows in the SocialVC become more complicated, compared with the normal VC. As the definition previously, the prosumers' role takes a dual role of customer and manufacturer, that is, prosumers are not only the product/service receiver, but also the supplier or manufacturer for product. Consequently, the material flow is changed to multiple paths for a single product in the context of SocialVC. For the same reason, the cash flow is also changed, and is not a single direction of flow, but a multiple path flow. The information flow is changed to multiple paths as well. Besides the major flows, there are also some other flows, such as people flow and machine flow. Supported by KSTs, the resource flows interconnect among "people–machine–material", "people–people", "people–machine", "machine–machine", as described in support layer2. For multiple products, the flows are even more multi-directional according to how the SMRs/SMGs/prosumers form. All flows are intertwined and more complicated, and can be called flow-networks (see Figure 5), compared with flows in the normal VC. With support from KSTs and formed from the social environment in the SocialVC system, all flows through flow-networks across each node can run in adaptive, autonomy and decentralization modes, as shown in Figure 5.

Meanwhile, management support is also important and should be defined to ensure that all processes operate smoothly and avoid uneven flows, with continuous optimization to make all resources produce the best capacity for value-adding. As shown in layer4 in Figure 5, the management system can contain data collection, data management, monitoring, communication, coordination, optimization, risk management, continuous optimization and supply management (not limited here), defined for various goals. Comparing with the normal VC, the connecting and interaction among nodes are not only dependent on process, but also interaction supported by the social sensor, RFID and CPSS in the context of SocialVC. Digital-driven technology enables various nodes/participants/prosumers to effectively connect and interact during order fulfilment, and avoid more non-value-adding activities due to poor communication, or untimely reaction, which happen often in the normal VC. With digital technology and management support, all SMRs work in an orderly and efficient manner to add value to the end product by means of the configured tasks.

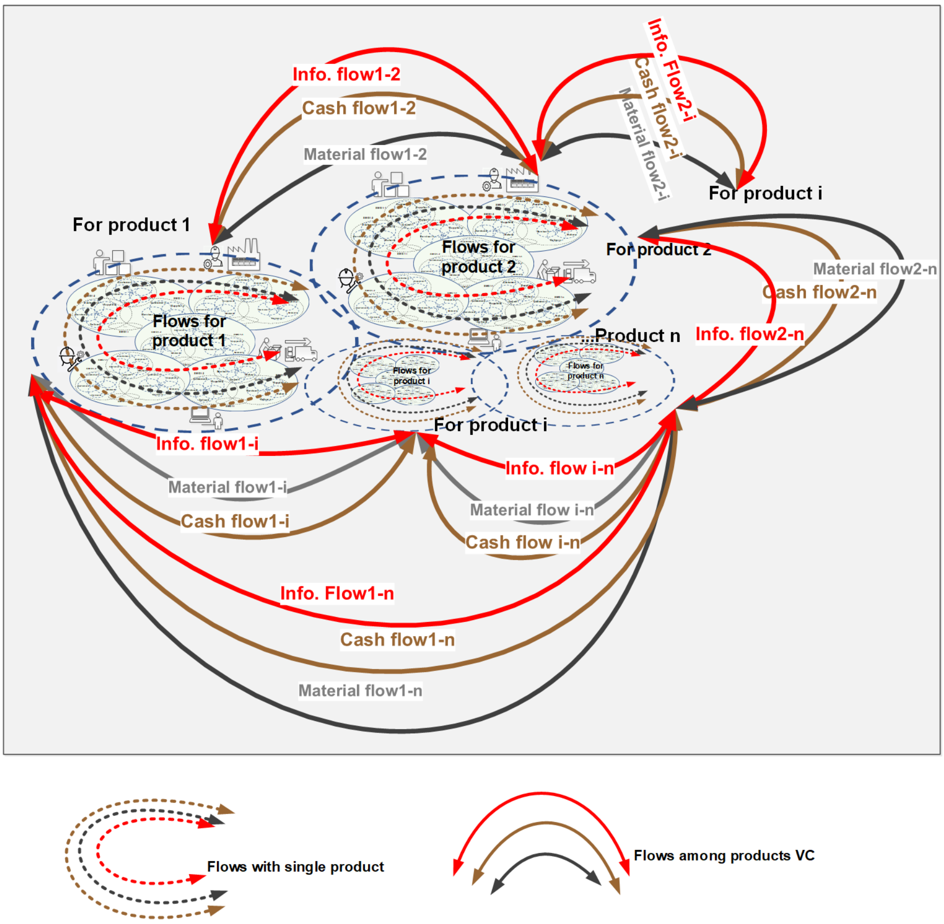

Figure 5. Flow-networks of the SocialVC system.

4.1.5. Layer5—Output Layer

Layer5 is for delivering the product/service to end customers appropriately. There are two kinds of deliveries from order fulfillment to customers, namely non-physical products/digital products and physical products. Digital products include all products which use data for the product, service, production and customer feedback, such as a software, data-based application or tool, a set of information, data for service, online training, and drawing and BOM (bill of materials) from engineering work. Physical products include all tangible items, such as books, various physical equipment, instruments, cranes, etc.

4.2. SocialVC Measurement Framework

To ensure that the SocialVC system operates in a stable and reliable way, and at the same time continues to optimize value-adding, measurement of the SocialVC system should be well defined and take into account monitoring of the performance of SocialVC. However, the performance measurement of SocialVC is still a new subject, even though some scholars have shown an interest in social performance (SP) [63]. For the normal value chain system, ASCM has defined the performance system in the SCOR (Supply Chain Operations Reference) model [64], which is a comprehensive system to measure the normal value chain. Most measurement of normal VC mainly focuses on delivery performance and cost performance, for instance SCOR performance. However, SocialVC needs the appropriate performance to measure how SocialVC meets the requirements of customers, how KSTs support the new system—SocialVC—and how manufacturing resources across the chain are efficiently used for adding value to the customers' order. The normal measurement system for the performance of normal VC is not able to cover the new requirements for the performance of the SocialVC.

4.3. Critical Success Factors for SocialVC Operation

To develop the performance of the SocialVC by measuring how the overall process behaves to create value and how the participants in the chain work together to meet the customers' requirements, this research uses a CSF tool as the basis for a performance measurement framework to measure the performance of the SocialVC.

CSF is an effective management tool that is strongly relevant to the strategic goals of enterprises [65]. This research extends the application of CSF to achieve success in the operation of SocialVC. CSF of SocialVC should take into account both the characteristics of SocialVC and value-adding tasks/activities for the required product/service through the value chain process.

Based on the characteristics and management requirements of SocialVC, this research suggests some main CSF to ensure operation of the process in the context of SocialVC. A logical relation between outputs from the SocialVC system and defined as three grouped CSF is illustrated in Figure 6. As Figure 6 shows, the value of output is relevant to the customers' satisfaction and products/services that meet the customers' expectations and achieve a win–win scenario. Regarding the requirement of success in the SlVC, we classify CSF as three groups that provide the core factors for success in the context of SocialVC, as below:

Group 1: information/data-driven CSF mainly includes two primary CSF: information/data transparency/sharing and communicating efficiently, which provide the major key basis for other CSF;

Group 2: technology and management-driven CSF, which is a supporting group and includes technology and management solutions to provide the relevant process and management skill/methods for value-adding capability;

Group 3: deliverability-driven CSF, which are directly linked to ensuring value-adding to product/service to meet the customers' requirements, supported by group 1 and group 2. The CSF of group 3 shows the key value-adding capacity to provide product/service to customers.

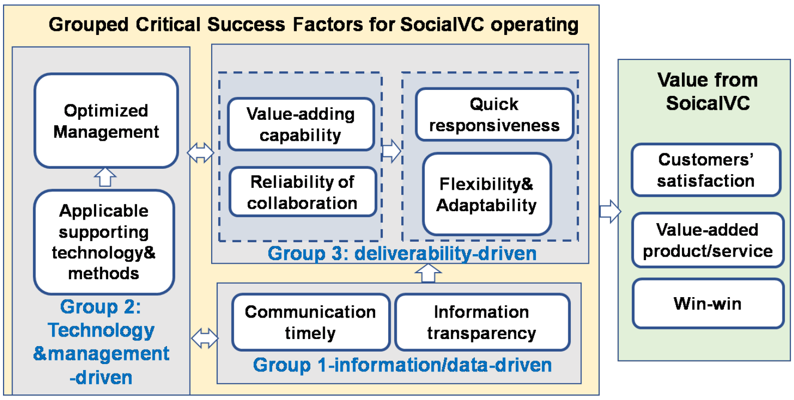

Figure 6. Grouped major CSF and relations with output from SocialVC.

These CSF lead to success in deliveries that create added value to the customers' requirements from SocialVC. Some CSF in SocialVC are similar to the normal VC; for example, information transparency/sharing is a key for the cooperation of participants across the supply chain. However, the even stricter requirements for SocialVC should be supported in the management process and supporting technologies to enable responsiveness and adaptability due to the characteristics of the social mode: being decentralized, self-adaptive, and needing self-organization and more involvement from MSMEs and individuals. Therefore, the process for information transparency/sharing of the relevant management should have a much higher requirement for SMRs to respond in a timely manner to the demands of the tasks or of customers. In addition, there are more highly prioritized factors in SocialVC to support flexibility and adaptability, which also relate to quicker responsiveness and more management commitment, and effective communication from all SMRs. As stated previously, CSFs are reflected in performance measurement, and some CSFs have a strong relation to KPIs, for instance quick responsiveness and flexibility strongly reflecting operational behavior of SocialVC. According to customer demand and characteristics in SocialVC, the above grouped CSF are defined as the most important factors according to SocialVC implementing. From a practical perspective, involved participants should develop and extend more customized levels of CSF based on the specific situation.

Based on the identified CSF, the relevant management system (see layer 4 in Figure 4) can be developed, including the relevant management process and approaches. Therefore, systematic management should be a research topic. It is noticed that management details are not a focus of this research, even though certain management elements are listed in the proposed architecture in Figure 4. Meanwhile, in order to quantify the CSF and measure the SocialVC system, the framework of performance is considered and discussed in the following subsection.

4.4. Performance Measurement Framework of VC

Comparing SCOR metrics for normal VC and taking into account CSF and characteristics of SocialVC, we propose a performance measurement framework in which high-level KPI (key performance indicators) are developed to evaluate and measure how the SocialVC system behaves in terms of value-adding activities/tasks for the relevant production and service according to customer requirements.

In the performance measurement framework, a primary/ high-level KPI is defined based on CSF and the strategic intentions of SocialVC (see Table 1). In Table 1, the primary SocialVC performance is listed and comprises a level of data/information supportability, cooperating-ability, technology supportability, management, delivery, value-adding capability and maturity of SC. Definitions of each primary performance and relevant examples are also made and shown in Table 1. Regarding the normal value chain, the KPI mainly focuses on delivery-driven performance to the customer and cost-driven performance for enterprises, such as the SCOR metrics developed by ASCM [64]. Regarding SocialVC in this research, more factors should be considered due to certain changes; for instance, involved participants become prosumers that link to SMRs/SMGs, communication is under the social environment, and various KSTs play an important role in the application of the SocialVC system. Consequently, CSF extends to more factors, and performance also includes more elements accordingly. As shown in Table 1, besides delivery performance and cost-driven performance, which are similar to with those in the normal value chain, more factors are taken into consideration in the SocialVC performance, such as more focus on data/information, communication/coordination, support technology, management, and maturity; and the definition of performance of value-adding capability is also expanded from the normal value chain.

Table 1. Primary measurement metrics of the social value chain.

No.	Metrics	Definitions	Examples
1	Level of data/ information supportability	Measurement that focuses on how effectively the relevance data system/process/program/activity behaves in data management towards the business goal, such as data collection, data analysis, sharing, etc. across the value chain	Accuracy, Completeness, Timeliness of data collection, Consistency of data, Revise timely, Quality of data analysis, Traceability, data/information richness for carrying out required tasks/delivery, Level of privacy & security of data
2	Level of cooperating-ability	Measurement that focuses on how effectively communication/coordination is carried out among participants (prosumers/SMRs/SMGs) across the value chain	Supporting data/information, Timeliness of responses and feedback, Efficiency of interaction process/techniques/social media/channels for communication/coordination/sharing
3	Level of technology supportability	Measurement that focuses on how the defined support technology supports relevant goals of process/management/prosumers	Convenience, Stability, Maintainability, Connectivity of multiple techniques, Connectivity for requirement, Enableability, Compatibility
4	Level of Management	Measurement that focuses on how defined management system with relevant process/role effectively to achieve relevant management goal	Achievement of goal, Maturity of management process, Development of people's skills, method of CI (continuous improvement) for optimization
5	Service level of delivery	Measurement that focuses on operational factors across the value chain to achieve both satisfaction of customers/prosumers, and win–win for all participants/prosumers of the value chain	Responsiveness to customer, Flexibility and adaptability to change, Rate of perfect order fulfillment
6	Value-adding capability	Measurement that focuses on the ability from all participants/prosumers across the value chain to carry out value-adding activity/task on product/service to meet the expectations of customers/prosumers	Total cash-to-cash cycle time, Total order delivery cost, Total of asset utilization of prosumers, Value of customer/prosumer; perceived value of product/service, Ability of innovation to create value for both customers and prosumers
7	Maturity of SocialVC	Measurement that focuses on how SocialVC operates in a resilient, stable, and healthy manner to deliver a product/service. Sl VC may define different maturity assessment models according to different management systems/processes with specific goals towards value-adding and win–win across the value chain	Maturity of data/information, Maturity of management/process across the chain, Maturity of overall cooperation/commitment of all prosumers/SMRs/SMGs

Well-defined KPI with multiple-levels not only can provide a comprehensive evaluation for understanding on the effectiveness and efficiency of the entire value chain system and value-adding capability in the context of SocialVC, but also provide a gap between the baseline (current KPI) and target (future KPI) by continuous improvement of systems/structures/processes. Therefore, a more detailed multiple-level KPI needs to be developed, guided by the proposed high-level KPI. Examples in Table 1 give more selections to define the detailed-level KPI even though this topic is excluded in this research. For instance, to achieve good performance, responsiveness to customers, flexibility and adaptability to change, and rate of perfect order fulfillment are associated with primary performance-delivery. All seven primer KPI can be broken down into more detailed KPI levels to develop the appropriate calculation accordingly, for better in-depth understanding of the entire SocialVC.

5. Conclusions and Future Research

As described above, this research presents a novel way of adding value via SocialVC, which provides more potential for enterprises to create value and strengthen their competition. The major contributions from this research work are summarized in this section, and directions for future research are also suggested.

5.1. Conclusions

Compared with the value-adding capability of the normal value chain, the proposed new perspective of value-adding in the context of SocialVC system can leverage the new value-adding mode provided by the SocialVC system in order to promote opportunities and capabilities for adding value for all involved participants. The proposed architecture of SocialVC can play an important role in forming the SocialVC system, which helps to understand how enterprises and customers can use the SocialVC system in dealing with coordinating various manufacturing resources, and how the value-adding activities/tasks made by SMRs/SMGs/prosumers are supported from various KETs and management systems. In reality, the SocialVC can mitigate the non-value-adding factors caused by certain issues in the context of the normal value chain. It can also promote a win–win scenario for all involved participants (prosumers/SMRs/SMGs) in the Social VC.

It can be concluded that there is plenty of value-adding potential from the enterprise perspective, especially for those MSMEs and individuals not easily involved in many manufacturing tasks in the context of the normal value chain. From the perspective of former customers in the normal value chain system, the role of customers changes to that of prosumers who can also be involved in the upstream manufacturing process to mitigate waste due to the ideas and manufacturing capacity of customers being neglected or not incorporated into the manufacturing system. As the manufacturers become SMRs/SMGs/prosumers, there is no clear line among enterprises/MSEMs/individuals and customers in the SocialVC system, and some issues that have been difficult to solve for a long time in the normal VC system must be greatly reduced, such as sourcing, service, and the roles of customers as discussed in Section 2.

Regarding the networking issue in the normal value chain, the new perspective in SocialVC is adopting social networking, such as Internet-based social media or platforms. Social networking not only allows feedback from all SocialVC participants, but also provides an effective way of interacting and communicating for collaborative value-adding activity with its downstream consumers (prosumers in SocialVC) across the chain. Social networking with other supporting technologies can minimize waste in networking in the context of the normal VC.

Regarding the high demand for mass customization, the customized product/service can be dealing with the SocialVC system, which provides an effective social network for stronger interacting and collaborating among various resources. Meanwhile, prosumers are one resource in the SocialVC; they have a better understanding of customization and individualization. Consequently, waste caused by understanding customers can be minimized in the context of SocialVC. With supporting technologies, such as social networking, big data, intelligent decisions, etc., the networked resources collaborate to contribute a lot of capacity/idea/knowledge for more value-adding activities/tasks in the manufacturing process, driven by much customization and individualization.

Regarding measurement of the SocialVC system's performance, the authors present a performance measurement framework considering the identified main CSF and characteristics of SocialVC. The primary/high-level KPI are defined in the performance measurement framework, and some examples of lower-level KPI are provided. With the high-level performance metrics, detailed low-level KPI with the relevant calculation should be further developed for evaluating how the SocialVC operates.

In brief, the SocialVC brings more potential for value-adding for all involved participants while reducing waste that is difficult to remove in the context of the normal VC. For this purpose, the SocialVC architecture provides a social networked manufacturing environment in which participants (enterprises/MSMEs/individuals) across the chain can collaborate to carry out order fulfillment, supported by KSTs and defined management systems. The theory of and knowledge about the SocialVC system still needs to be developed towards a more systematic and mutual SocialVC which fosters the capability of enterprises to add value and address issues relevant to the concerns of value-adding in the context of the normal VC.

5.2. Future Research

Deepening and exploring the various potentials of value-adding in the context of SocialVC remains a major area for future research. It is also important to draw on certain existing lean tools to analyze or identify the further potential of value-adding, such as value stream analysis/value stream mapping. In the context of digital technology, it would be crucial to search out more value-adding potential supported by advanced digital technology applications.

Regarding SocialVC networking, exploring more support technology and relevant computing methods for decision-making on the optimization of the shape of SMRs is needed. As described in Section 4, SMRs are characterized by socialization, decentralization, self-organized and specialization, which are different from the normal organization with centralized management. Another important research area in the future will focus on intelligent decision-making in more optimized modes for interacting and collaborating with SMRs' shape, in order to carry out customers' order fulfillment, in particular, orders with mass customization and mass individualization. For example, a topology model for enterprise relationship network in the context of the social manufacturing is introduced by Jiang et al. [54].

Regarding the high demand for mass customization, this is associated with the above research area: more optimized SMR shape with more effective interaction and collaboration to help in dealing with mass customization or mass individualization. In addition, from the business perspective, there is a need to improve the overall production planning mode in the context of the SocialVC system, including a socialized integrated planning mechanism in an ecosystem of the socialized business model.

Regarding the performance measurement of the SocialVC system, the original intention of this research was to propose a new perspective on value-adding for enterprises/customers, so performance-focused attention is limited in this paper, although the authors propose a high-level performance measurement framework which is helpful in developing detailed multiple low level KPIs with calculations to measure and evaluate the SocialVC system in order to optimize the system and create more value-adding potential. Liu et al. paid attention to social factors in evaluation of the supply chain management system. From the perspective of preferred suppliers, they developed an SSSE indicator system that considered economic, environmental, and social factors, and the cloud probability dominance relations (PDR) method was used for the selection of the optimal sustainable supplier [66]. From the perspective of comprehensively evaluating the performance of the SocialVC, a bigger effort is still needed to develop detailed performance measures to evaluate the major business process across the SocialVC. Further research on the SocialVC system is needed on the behavior of involved participants, such as behaviors among enterprises, MSEM and individuals who are involved in value-adding activity in the SocialVC system as prosumers, as their behavior impacts both the efficiency of the delivery of the SocialVC system and the value-adding capacity for all involved participants.

Regarding the product-lifecycle-based value chain that is actually not the focus in this paper, it is nevertheless still an important topic in SocialVC, for instance, how to build a sustainable socialized manufacturing value chain that covers the product lifecycle. More effort should be put into the product-lifecycle-based value chain: for example, Liu et al. proposed a graph-matching model that can calculate the similarity score to solve the matching problem in the crowdsourcing mechanism between the collaborative design crowdsourcing task network graph and the designer network graph [67]. There are more issues in the product-lifecycle-based value chain which could be an area focused on in the future. Moreover, future research may also focus on different industries to establish various industrial social systems according to the needs or specific purposes of the particular industry. In this area, some attempts have been made. For instance, a digital monitoring and management platform for urban construction crane machinery has been established in Ningbo, China [45]. More than 10,000 various construction crane equipment items have been connected to the digital platform, with 869 linked enterprises and 23,139 operators, and more than 3000 construction sites in 2022. This platform creates a city-wide socialized entire value chain management for the construction industry. This case from the crane industry provides a sample of the SocialVC of various industries which have a special purpose, and this can also be one future research direction.

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