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The Promises and Challenges toward Mass Customization of Healthcare Services

Shuang Ma ^{1,*} , Xiaojin Zhang ² and Songlin Chen ³¹ School of Economics and Management, University of Science & Technology Beijing, Beijing 100083, China² Office of Clinical Epidemiology, Analytics and kNowledge (OCEAN), Tan Tock Seng Hospital, Singapore 308433, Singapore³ School of Mechanical & Aerospace Engineering, Nanyang Technological University, Singapore 639798, Singapore; songlin@ntu.edu.sg

* Correspondence: mashuang@tju.edu.cn

Abstract: The healthcare industry is confronted with the challenge to offer an increasing variety of healthcare services while in the meantime controlling rapidly increasing healthcare costs. Mass customization has been proven to be an effective strategy to fulfill customers' individual specific needs with high efficiency and low cost in the manufacturing industry. This paper investigates the theoretical feasibility and practical applicability of adopting mass customization as a conceptual framework for designing a healthcare service delivery system. The nature of healthcare delivery systems and their evolution are discussed relative to those of manufacturing systems. Recent research in personalized medicine, consumer-driven healthcare, consumer healthcare informatics, and integrated healthcare delivery is reviewed as enabling technologies towards mass customization of healthcare services. By synthesizing these scattered efforts in different streams of literature, this paper concludes that mass customization can contribute to the redesign of healthcare service systems, and delineates a roadmap for future research.

Keywords: mass customization; healthcare services; service industry; roadmap



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1. Introduction

Healthcare systems around the globe are faced with enormous challenges to deliver high-quality healthcare services at affordable costs to an increasingly long-living and aging population [1–3]. Despite increasing healthcare spending, the rapid growth of demand for healthcare services has outpaced that of the supply of medical resources in both developing and developed countries [4,5], resulting in restricted access to care, congested hospitals, long waiting queues, and compromised quality, among many other problems [6,7]. Given the already high percentage of healthcare expenditures in many national economies, the long-term sustainability of a healthcare system cannot rely solely on capacity expansion in terms of more hospitals, doctors, nurses, and more public funds, but requires a redesign of the healthcare service delivery system to make it more efficient and cost-effective [8–10]. The World Health Organization advocates three goals in improving healthcare system performance, namely *good health, responsiveness to the expectations of the population, and fairness of financial contribution* [5]. Similarly, the Institute of Medicine (IOM) of the U.S. calls for a redesign of healthcare systems to deliver healthcare services that are *safe, effective, patient-centered, timely, efficient, and equitable* [11].

However, researchers are pointing in different directions and there is a lack of an overarching conceptual framework regarding healthcare system redesign [12]. More specifically, there is a missing link between policy discussions at the system level and practical solutions on specific issues. Recent years have witnessed many initiatives toward establishing a new paradigm for healthcare service provision and delivery, including managed care, total quality management, lean healthcare, etc. However, these initiatives tend to focus on specific

aspects of healthcare like cost, quality, and process efficiency. A fundamental challenge that remains to be addressed lies in *how to fulfill a rapidly growing and increasingly diversified demand for healthcare services with a rapidly expanding portfolio of offerings but limited resources*.

If history could be of some reference, the manufacturing industry can inspire the redesign of healthcare delivery systems by adopting mass customization. On the one hand, healthcare is similar to manufacturing in many ways and the healthcare industry has been historically learning from the manufacturing industry, in both management innovation and technology adoption [13–15]. Some researchers have explicitly called for a redesign of the healthcare system based on mass customization [16–18], and other streams of research, e.g., consumer-driven healthcare [19,20] and personalized medicine [21–23], are also pointing in this direction. On the other hand, healthcare remains fundamentally different from manufacturing in the sense that it is essentially a service, where people's health or life are at stake [24,25]. The different quality standards, regulatory frameworks, and industry structures make it a legitimate concern regarding how far the analogy between manufacturing and healthcare can be carried when it comes to adopting mass customization for healthcare.

Up to the current date, little research has been devoted specifically to mass customization of healthcare services, although the topic has been touched upon in many fields of research, including medical research, operations management, informatics and technology management, etc. [26]. The challenge, which is also the purpose of this study, is to compile, analyze, and connect the dots that are scattered in many original research papers across many different disciplines of research. By synthesizing these scattered efforts in the literature and organizing them under the roof of a mass customization conceptual framework, this paper aims to provide a point of departure for debate and a roadmap for future research on mass customization of healthcare services. In the rest of the paper, Section 2 presents a general structure and the key characteristics of a healthcare system. Section 3 introduces the concept of mass customization and discusses its development in manufacturing and service industries. Section 4 postulates mass customization as a potential paradigm for healthcare delivery and reviews relevant research in the literature. Section 5 delineates a roadmap for future research by pointing out some critical issues for further investigation of the mass customization of healthcare services.

2. Healthcare as a Complex Service System

2.1. The Nature of Healthcare

According to the WHO, healthcare indicates not only the physical needs of ill patients that need to be addressed but also their psychological, social, spiritual, and environmental needs [5]. Specifically, social needs are considered as critical medical needs by 80 percent of physicians [27]. Social needs mainly refer to housing, food, public benefits, employment, etc. While hospital-based care providers cannot address patients' social needs without social support from wider organizations, this wider healthcare delivery system is relatively complicated, with multiple stakeholders and interactions. Thus, in this study, hospital-based healthcare is primarily considered to illustrate how mass customization works with healthcare delivery system redesign.

There is ongoing debate regarding what hospital-based healthcare really is and how it is different from manufacturing and other service industries. On the one hand, healthcare, like other products and services, is an economic resource that is subject to market dynamics, in terms of supply and demand [4,28]. Patients can be taken as consumers who demand healthcare to fulfill their medical needs. Healthcare providers supply healthcare, in terms of medicines and/or treatments, in exchange for a fee. In this sense, the provision and consumption of healthcare are not that different from the production and consumption of manufactured products. On the operational level, there are also many similarities between healthcare delivery and goods production. Patients can be treated analogously as "jobs" to be processed, doctors as "technicians", hospitals as "factories", patient pathways as "routes", etc. [29,30]. Based on such similarities, many operations management tech-

niques that originated in manufacturing are finding increasing applications in healthcare, including hospital capacity planning, emergency department staffing, and surgery room scheduling [10,31,32].

On the other hand, healthcare is fundamentally different from manufacturing, in the sense that it is essentially a type of service, which is characterized by such properties as *simultaneity*, *perishability*, and *intangibility* [18,33]. The diagnosis and prescription involved in healthcare is a problem-solving process that is experimental in nature, which resembles that of other professional services, such as legal counseling, financial advisory, and business consulting [34]. But healthcare differs fundamentally from these services as well because it deals with people's health, which biologically defines the well-being of a human being. This basic biological difference between health and other assets makes it difficult to determine a market value for healthcare, and it exaggerates other forms of market failure, such as moral hazard and asymmetric information [12]. As a result, healthcare carries significant social and moral values that go beyond its economic value.

In the traditional healthcare service system, standardization is one of the most important guidelines for designing the procedure of service delivery and reducing unwanted variation in diagnosis and treatment. Standardization can facilitate the comparison between services, clinicians and organizations, thus improving the quality of healthcare services [35,36]. However, in a system of healthcare standardization, each patient would be treated with the same prescribed process, irrespective of patient preferences. In recent years, the trend of healthcare is becoming more inclined towards personalization and customization, with the aim of improving the tailoring healthcare to an individual's unique characteristics and preferences [37,38]. More significantly, patients can be involved as active partners to "co-produce" care with health professionals, especially those with chronic conditions [39,40]. However, customization would be the opposite of standardization, as it would involve different ways of organizing and delivering healthcare [41,42]. Standardization asks professionals to encounter the logic of evidence-based medicine while customization aims to manage the uniqueness of the process [42,43]. In a healthcare delivery system, standardization and customization are both major principles. Thus, how to balance the relationship between them to make a trade-off is the key challenge. Mass customization, adapted from the manufacturing industry, can reap the benefits of standardization while simultaneously involving patient preferences in the process of care delivery. Meanwhile, a standard and flexible healthcare process can be constructed, based on the concept of mass customization to jointly optimize customization and cost control. However, coordinating healthcare with mass customization primarily requires the following: (1) an understanding of how to involve information technologies in the healthcare delivery process; (2) patient self-management in the co-production of care services; and (3) defining the criteria that care customization is based on.

2.2. Healthcare Delivery Systems

The WHO defines a health system as including all the activities whose primary purpose is to promote, restore, or maintain health [5]. Tien and Goldschmidt–Clermont summarize healthcare as a complex service system that consists of an integrated and adaptive set of people, processes, and products [25]. The scope of a health system is so broad that it is more appropriate to model it as a system of systems, which has a diverse number of agents and uncountable interactions [44,45]. Similar to IOM [11], this paper defines a healthcare delivery system as activities that are directly involved in the provision, transaction, and consumption of healthcare services, as in Figure 1.

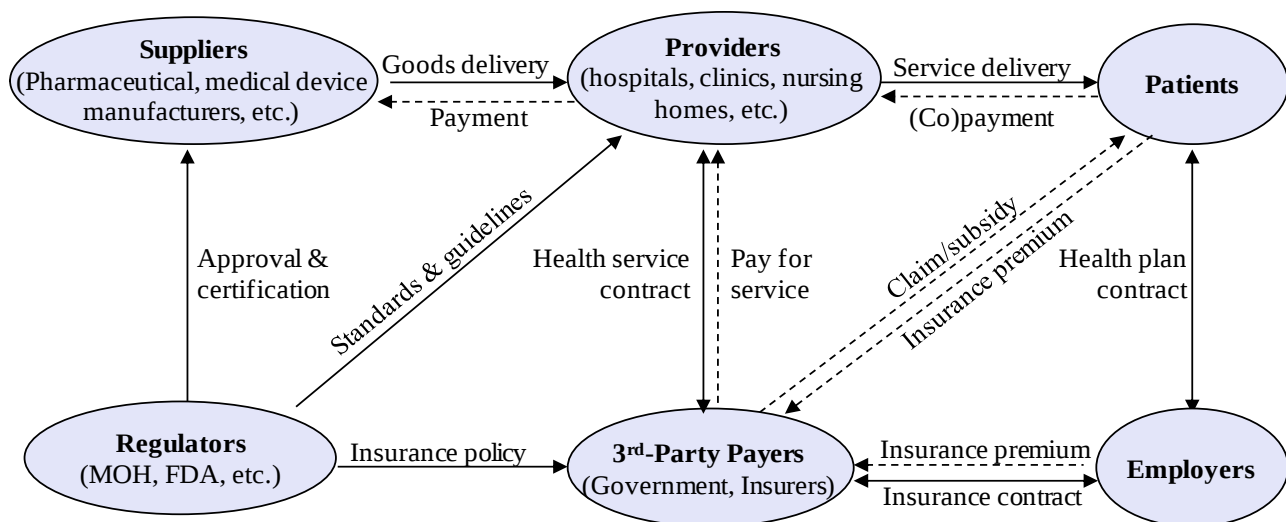


Figure 1. The structure of a general healthcare delivery system.

The backbone of a healthcare delivery system lies in the *supplier-provider-patient* axis. The suppliers (pharmaceutical companies and medical device manufacturers, etc.) supply medicine and medical equipment, based on which healthcare providers (hospitals, clinics, nursing homes, and households, etc.) provide healthcare services, in terms of diagnoses, prescriptions, and/or surgeries to patients. The product and service flow are quite straightforward but the reverse capital flow is more complicated. Patients' payment for healthcare services depends on their insurance plans. For those without any insurance, the whole price of healthcare services is borne by the patients. For those with insurance, patients pay a portion of the healthcare services as a co-payment, and third-party payers (including government and insurers) are responsible for the rest. There is usually a complex contracting and auditing relationship among patients, employers, third-party payers, and healthcare providers regarding the insurance premiums and claims of healthcare expenses. Furthermore, healthcare delivery systems are usually highly regulated by various government agencies regarding safety, quality, equality, etc. Therefore, healthcare system redesign must focus on coherent communication across different parties in the system [45,46].

3. Mass Customization

3.1. Mass Customization Concept

The concept of mass customization was first expressed in Toffler's book *Future Shock*, in which he predicted that future manufacturing enabled by information technology would be able to provide customized products on a large scale with little or no extra cost [47]. The term 'mass customization' was first coined by Davis [48] in his book *Future Perfect*, in which he described a trend where companies sought to micro-segment markets and offer unique products and services to customers. It was Pine and his colleagues who popularized the concept of mass customization and ignited a wave of academic research and industrial experimentation [49]. In their work, mass customization was defined as the ability to provide individually designed products and services to every customer through high process agility, flexibility, and integration. Many authors propose more practical definitions by describing mass customization as a system that uses information technology, flexible processes, and organizational structures to deliver a wide range of products and services that meet the specific needs of individual customers, at a cost near that of mass-produced items [50–53].

3.2. Value Creation in Mass Customization

Under mass customization, customers act proactively as co-designers or co-producers by providing key design or production inputs [54]. The key principles underlying mass

customization are *economies of scope* and *customer integration* [55]. A precondition of mass customization is that a fragmented market with diversified customer needs exists [53,56]. By offering a large variety of products and engaging customers in product creation, mass customization is able to fulfill customers' individual-specific needs, in terms of fit, function, and/or aesthetics [57]. From a manufacturer's perspective, the success of mass customization hinges upon its capability to counterbalance the additional costs associated with large product variety, increased operational complexity, and loss of economies of scale. In the last two decades, many technologies have been developed to address these challenges in mass customization. For example, platform-based design methodologies have been developed to design product families that can cater to diversified customers' needs, while maintaining a relatively stable architecture that can be reused [52,58]; decoupling and postponement have been recognized as effective supply chain strategies that can achieve high responsiveness to customer orders with minimum inventory costs [59,60]; and information technologies, like user toolkits, are able to facilitate the task of customer need elicitation and product definition.

In general, the value proposition of mass customization can be summarized as giving customers choices that best match their individual needs, and enabling producers to interact directly with customers, thus efficiently utilizing resources with minimum wastage. The key to the success of mass customization lies in the capability to seamlessly engage customers in the value creation process by involving them in the right tasks and giving them the right tools [61,62].

3.3. Mass Customization in Service Industries

Although mass customization has been most discussed in the context of manufacturing, its basic principles and concepts can be applied to service industries as well [63,64]. It has been recognized that services are fundamentally different from products in the sense that they are intangible and perishable, and their production and consumption are simultaneous [33]. As a result, services cannot be kept as inventory or delivered in an intermediate form. Despite these apparent differences, there are many similarities between manufacturing and service operations. Many management and technology innovations originally developed in manufacturing industries have found applications in service industries. Citing examples like McDonald's, Levitt [65] took services as "manufacturing in the field" and advocated a production line approach to manage service operations. Sundbo [66] postulated a thesis of convergence between service and manufacturing organizations based on modularization of service production.

Services have an inherent element of customization, as customers are both recipients and co-producers [33]. A critical challenge faced by many service operations is how to efficiently handle customer-introduced variability [67]. The general value proposition of services, in terms of customer integration, customization, and efficiency, is consistent with that of mass customization. Key concepts of mass customization, e.g., value co-creation, modularity, and flexibility, can be transferred from manufacturing to services. Similar to modular product families, modular service portfolios have been proposed as a methodology for service design [63,66,68]. Flexible service processes have been proposed as a solution to handle the high variability in customized service requests. Mass customization is finding applications in a wide range of service industries, including finance, education, wireless communication, etc. [69].

4. Towards Mass Customization of Healthcare Services

Contemporary healthcare delivery systems are mainly still operated on the basis of a mass production paradigm. Mass customization has a special appeal to healthcare delivery, as every patient is biologically different, and healthcare service personalization thus generates a fundamental value-adding for patients [70]. Science and technology advancement, both in medicine and other disciplines like information and communication

technology, have fundamentally changed the way that physicians and patients interact, and how healthcare services are delivered [71,72].

4.1. Evidence-Based and Personalized Medicine

In much the same way that physics and chemistry provide the scientific foundations of modern manufacturing, healthcare service delivery is governed by the science of medicine. Traditionally, medical prescription and treatment were conducted through physical symptom observation, intuitive experimentation, and a process of trial-and-error. With the advancement of medical knowledge and technology, physicians are able to diagnose and deliver treatment with increasing accuracy and precision. Christensen's "intuitive → empirical → precision" framework provides a succinct description of the transition of healthcare service provision as the knowledge of medicine accumulates and advances [13] (Figure 2).

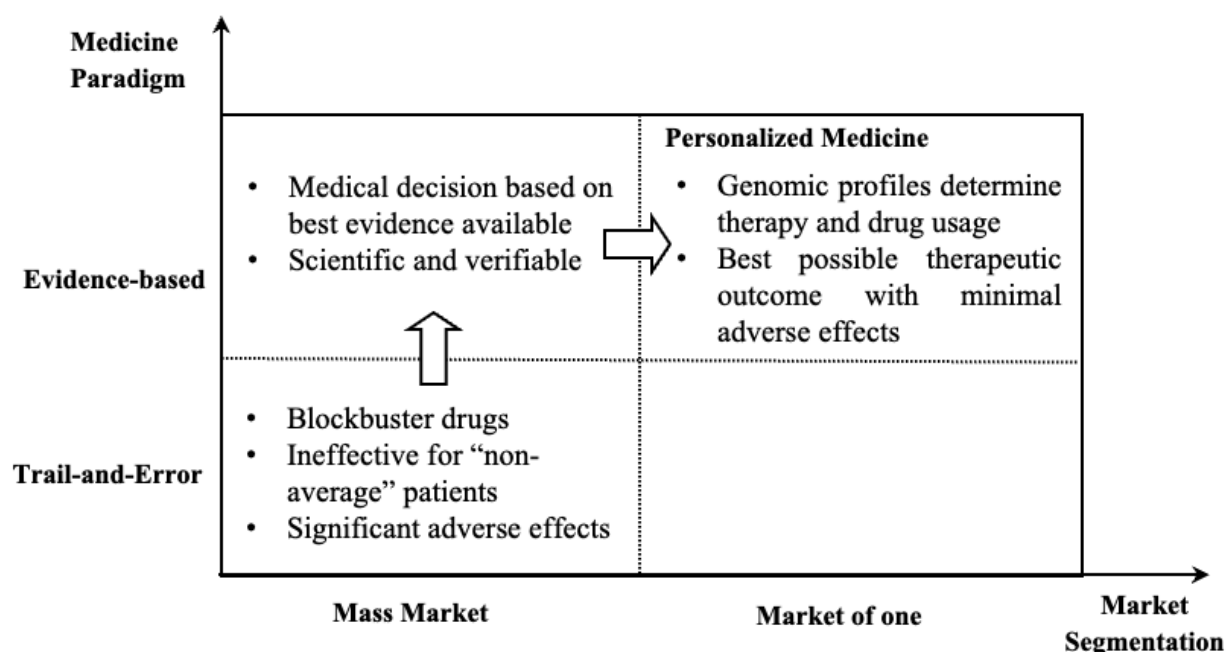


Figure 2. Paradigm Shift in Medicine.

The predominant paradigm for medicine development is to seek a blockbuster solution for a mass market. New medicine is usually developed targeting a representative condition or an "average" patient. The developed drug is then tested with selected patients in clinical trials. The results are compiled statistically to determine the effectiveness of the drug, in accordance with the "average" patient so that the maximum market can be addressed. However, increasing evidence has shown that many patients, especially those with unique medical conditions, are often not responsive to the so-called blockbuster drugs and, even worse, significant adverse effects are often observed [73]. It was also found that medical decisions are complex, highly uncertain, and prone to human errors [74]. For the same illness, there is a wide range of variation, in terms of treatments and effectiveness across different physicians, hospitals, and regions. Such variations imply a "quality chasm" in healthcare service delivery [11].

Evidence-based medicine seeks to address variability in healthcare service delivery by anchoring medical decision-making upon verifiable evidence. Evidence-based medicine is defined as "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" [75,76]. The basic premise of evidence-based medicine is that there is one, and only one, best prescription and treatment for a given condition of a specific patient. Although every patient is unique in terms of medical conditions and needs, the delivery of healthcare should be at the discretion of individual physicians, who are able to synthesize all of the important information about the patient [77]. A recent

development in healthcare information has made it possible for medical professionals to integrate clinical expertise and external evidence when making decisions about the care of individual patients. Thus, this development in evidence-based medicine establishes a foundation for capturing medical knowledge at a population level, while in the meantime allowing customization of healthcare services tailored to individual patients.

Advancement in the field of genomics further pushes the boundary of medical knowledge and makes it possible to develop personalized medicine, which promises more potent and precise medical treatment that can be adjusted to an individual patient's genetic information and other unique characteristics [78,79]. Personalized medicine is prescribed based on an individual patient's genetic profile, susceptible health conditions, and responses to a particular therapy. In other words, personalized medicine can eliminate unnecessary treatments, minimize the potential for adverse effects, and improve patient outcomes. Personalized medicine thus paves a way to design a healthcare delivery system based on mass customization.

4.2. Consumer-Driven Healthcare

Most contemporary healthcare systems can be described as supply-driven and physician-centered, in which physicians choose the products/services purchased by patients or by third-party payers on behalf of the patients [5,80]. The physician-centric structure generates a number of inefficiencies. First, there is an inherent conflict of interest. Healthcare providers are usually paid based on the services they provide, a practice that is often referred to as "fee for service". Under this compensation structure, physicians are motivated to over-treat a patient by means of additional tests or expensive procedures [81]. Such conflict of interest also occurs upstream in healthcare supply chains. The financial arrangement between healthcare providers and suppliers of medicine or medical devices may steer clinical decisions toward high-cost solutions [82]. Second, the high costs of litigation and malpractice insurance motivate physicians to practice defensive medicine, which often has minimal clinical value for the patient [83–85]. Third, as patients bear little of the direct cost of healthcare in traditional health coverage, they tend to over-consume medical resources by demanding expensive medicines or treatments [86]. Given the loopholes listed above, there are enormous efforts by insurers to audit and control medical claims and by governments to regulate the healthcare industry, which translates into high overhead costs.

Consumer-driven healthcare promises to address many of the inefficiencies. Herzlinger [19] describes consumer-driven healthcare as "a new model of health coverage", which "places control over both costs and care directly into the hands of employees (patients)". Powell and Laufer [80] define consumer-directed healthcare as "a systems approach that motivates individuals to shop for providers based on publicly available information regarding price and quality". Despite the differences in definitions, consumer-driven healthcare refers to a market-based approach for health insurance transactions. By putting patients in charge of healthcare dollars through personal Health Savings Accounts (HSAs) or other similar payment products, consumer-driven healthcare motivates patients to be discretionary in healthcare spending and forces healthcare providers to compete for patients' patronage. Thus, a shift towards consumer-driven healthcare can re-align the incentives of various parties in a healthcare system towards delivering superior value to patients, and the competitive pressure among providers could spur productivity and innovation that will improve quality and drive down costs [20].

There is ongoing debate regarding the novelty and viability of consumer-driven healthcare. Proponents believe it to be a revolution that will change the entire system, while critics consider it as no more than a tweak of the current system [87–89]. Some of the critics believe that patients do not always have the opportunity to shop for the best healthcare service because of limited supply capacities for many conditions [88]. Besides, unlike other commodities, the quality of healthcare service is difficult to judge even for sophisticated patients, making it easy for healthcare providers to compete on cost alone, ignoring quality and equity [90]. Finally, insurance will continue to be vital since healthcare is notoriously

expensive, and consumers with insurance will be shielded from the actual cost of their care, leading them to be less-than-thrifty buyers who may accept services offered by providers who stand to profit from them [91]. However, consumer-driven healthcare, in general, attempts to bring commercialism into healthcare and employs the invisible but powerful hand of market competition as the driving force to improve efficiency and quality, and reduce costs. Although commercialism is controversial, it is the most promising route towards re-aligning the incentives and unleashing innovation in an increasingly complex and dysfunctional healthcare system. As pointed out by the WHO [5], “If services are to be provided for all, then not all services can be provided”. Despite various challenges, consumer-driven healthcare will steer the healthcare system toward the needs of individual patients, which resonates well with the conceptual underpinnings of mass customization.

4.3. Consumer Health Informatics

In parallel to the development in fundamental medical science, there has been tremendous progress in information and communication technology (ICT) on the front end with patients [92–94]. Traditionally, physicians had tight control over all medical information. However, there is an increasing trend of reaching patients directly through computer networks to facilitate education, decision-making, communication, and many other activities. Consumer health informatics is emerging as “the branch of medical informatics that analyses consumers’ needs for information, focusing on informatics from consumer or patient perspectives [92,95]; studies and implements methods of making information accessible to consumers [96]; and models and integrates consumers’ preferences into medical information systems” [96,97].

Through the Internet, such as web services and open data sources, widely accessible medical information greatly influences the way patients learn, think and communicate with physicians [98]. Firstly, patients are well equipped with fundamental medical knowledge, including sickness prevention, disease symptoms, self-management, self-treatment and functional recovery, etc. For example, a social networking health site called PatientLikeMe enables members to find and communicate with fellow patients, gain social support, and learn first-hand about ways to cope with and manage diseases [99]. Although this information cannot replace physician visits, it can make it possible for individual patients to be actively engaged in healthcare decision-making [100,101]. Secondly, Electronic Health Records (EHR) have found increasing application in healthcare, and promise great potential for improving efficiency and saving costs [102–104]. Last but not least, the development of expert systems can support complex medical decision-making by synchronizing the patient’s self-updated treatment outcomes, personal risk factors, and scientific evidence.

Information technology is emerging as a powerful force that leads healthcare service delivery towards mass customization. The availability of consumer informatics provides cheap and effective means to link personal information to healthcare resources. Healthcare providers can communicate with individual patients and involve them in the healthcare delivery process. Patients are becoming better informed, and are more actively involved in the healthcare delivery process with the development of health informatics [101,105,106].

4.4. Healthcare System Decentralization and Integration

The delivery of healthcare is essentially a type of service that deals mainly with processes, instead of products, as in manufacturing. At the operational level, the healthcare delivery process is a collection of care services, which consume resources and constitute points in time. We are seeing a shift toward an increasingly complex and decentralized healthcare system, which is a globally common healthcare reform process [107]. Decentralization in the healthcare system indicates authority and power transfer from a central level to peripheral levels, closer to patients [108]. The traditional healthcare delivery system centralized around hospitals is giving way to a more decentralized system that involves community hospitals, nursing homes, and individual households [40,107]. Given the large diversity of processes involved in a decentralized healthcare system, the lack of system

integration has been recognized as a key challenge to the delivery of customized patient care [109–111]. For example, an increasing number of patients with chronic diseases require care services across different providers [112]. Poorly coordinated care between acute and long-term providers can result in ad hoc transitions and non-optimal care delivery. Many patients have experiences with conflicting medical advice, duplicate tests, and unnecessary visits. There are emerging trends toward individual patient involvement in healthcare delivery and system-level integration. Integrated healthcare services systems coordinate across different levels and sites of healthcare, including functional integration, organization integration, professional integration, and clinical integration [113]. An integrated healthcare system aims to provide patients with a continuum of health promotion, disease prevention, diagnosis, treatment, disease management, rehabilitation, and palliative care services [113]. Porter and Teisberg [114] suggest that information transparency established across different providers can improve integration in the healthcare system. Patient involvement in healthcare system integration can empower patients through health education, shared decision-making, supported self-management and self-treatment, and community engagement. There are several possible methods to engage patients in the integrated healthcare system [115], such as patient education through self-management programmes, patient choice of provider through decision aids and compliant systems, patient involvement in treatment and care decisions by patient consultation aid systems, and so on. One of the most famous examples of patient education is the English Expert Patient Programme. In this programme, patients are educated on how to manage and live with their conditions and improve self-efficacy and energy levels. This programme was found to be cost-effective, since the reduction of overall service utilization offsets the cost of the intervention [116].

Christensen et al. [13] propose “focused value-adding” hospitals and clinics as a strategy to strike a balance between efficiency and organizational flexibility, which is similar to the mass customization model in manufacturing. Value-adding in healthcare delivery calls for the healthcare system to create more value for patients, focusing primarily on patients’ health outcomes. Focused value-adding processes are organized to optimize the procedure to achieve consistent delivery of standard care. An interdisciplinary group of care providers comes together to design and deliver comprehensive solutions for a segment of patients whose health and related circumstances create a consistent set of needs. By focusing on a specific and well-defined condition or procedure, focused value-adding processes are able to significantly reduce cost and improve quality. From a system-level point of view, complementary or partially overlapping value-adding process hospitals and general hospitals are able to respond flexibly to a dynamic mixture of customized and standardized healthcare processes.

There has also been a growing stream of research concerning strategic system integration and coordination [117]. Bohmer [118] puts forward a patient-oriented approach to design and deliver custom and standard care processes. Sets of standardized clinical processes are selected from a pre-defined protocol and combined seamlessly to treat patients, which is similar to product configuration in mass customization. This approach enables the healthcare system to both master custom care and deliver consistent standard care to obtain advantages in quality, cost, and diversification. Dowd [119] proposes “coordinated agency” and “autonomous consumers” as two models to engage patients in healthcare delivery. In the former model, care providers act as patients’ agents and address challenges in the market on patients’ behalf. In the latter, the consumer-directed health plan model envisions autonomous, well-informed and price-conscious consumers shopping among providers unconstrained by organizational affiliations. Meyer et al. [120] propose a platform of process for individual services. The authors apply a modular approach to designing service packages and show improvements in care delivery. This research examines how the adoption of the platform design concept can improve the integration of healthcare delivery systems. Zhang [121] investigates the adaption of the platforming concept in developing healthcare service families due to the unique characteristics of hospitals. The author points

out that a platform of healthcare systems is not a physical component but a form of an abstract system to integrate service providers and patients.

In sum, an increasingly integrated healthcare system makes it possible to engage patients in healthcare service delivery, so that they are able to participate in medical decision-making and take responsibility for their own health. Integration also facilitates coordination among care providers, so that comprehensive healthcare services based on individual patients' needs can be offered in an efficient manner. Thus, an integrated healthcare system with processes that can be flexibly combined provides a key enabler to achieve mass customization of healthcare services.

5. A Research Roadmap

Figure 3 summarizes the key development in a diverse field of research toward mass customization of healthcare services. It can be concluded that patients' increasing awareness and expectations are leading to increasing demand for customized healthcare services. In the meanwhile, advances in enabling technologies, like evidence-based and personalized medicine, information and communication technologies, consumer-driven healthcare, and consumer health informatics, are converging to make it possible to deliver customized healthcare services with increasing accuracy and efficiency. Thus, from the perspective of both supply and demand, healthcare service delivery is moving towards the paradigm of mass customization.

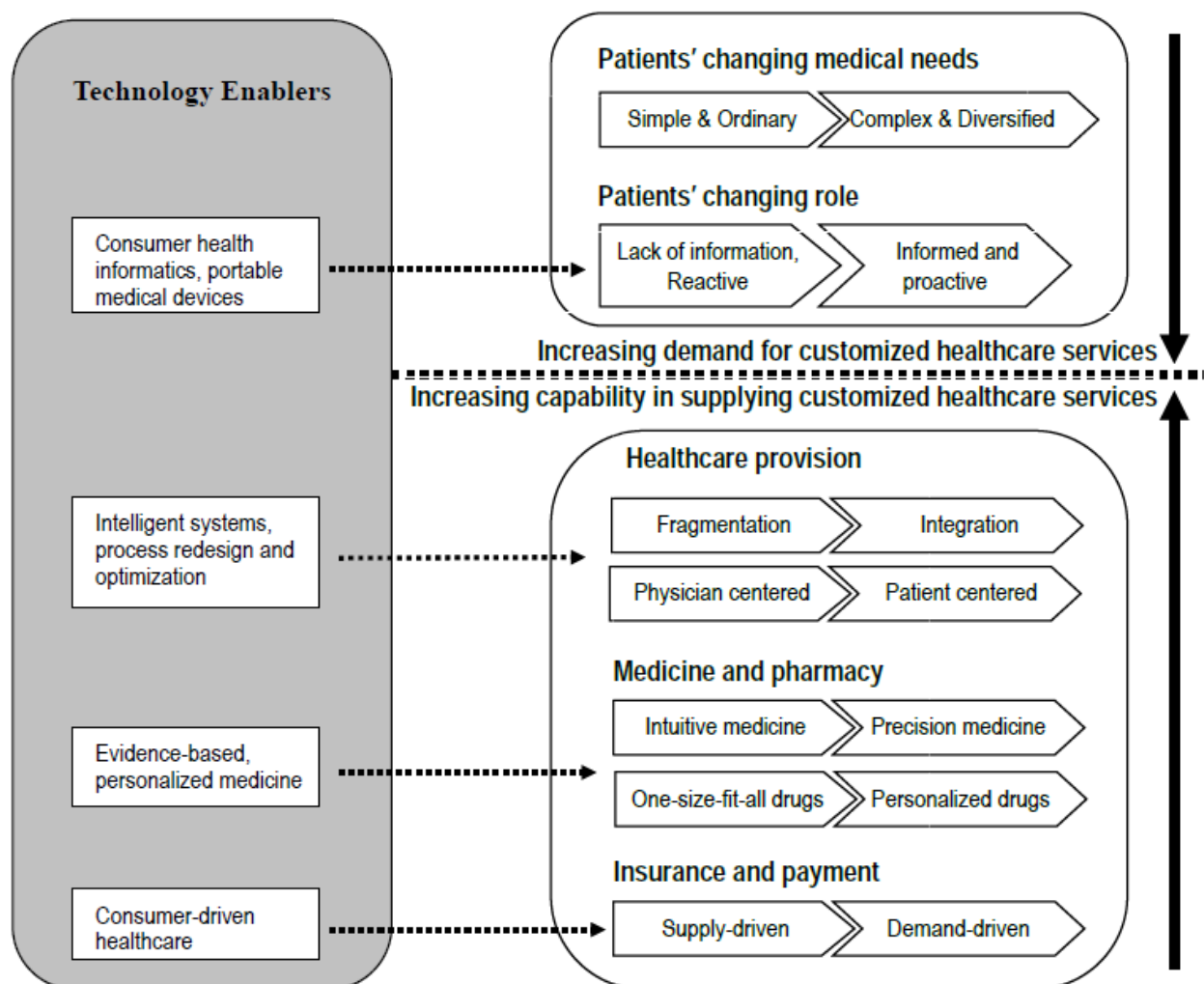


Figure 3. Key development relevant to mass customization of healthcare.

However, there is still a long way to go for mass customization to be implemented as a viable paradigm for healthcare service delivery. This paper suggests a number of specific areas for future research.

5.1. Healthcare Process Redesign

Mass customization is a demand-driven, customer-centric system. In the context of healthcare, this means healthcare processes need to be delivered based on patients' individual-specific needs, while in the meantime, processes need to be designed to achieve high efficiency [122]. Thus, process redesign is one of the most important research areas in enabling mass customization of healthcare services. A prerequisite of process redesign is to understand how healthcare services are delivered from individual patients' perspectives, instead of based on the current department or clinic structure organized by physicians. In other words, it is essential to map out clinical pathways based on individual patients' conditions. Pathways with correct ordering and network constructs are helpful in matching patients' medical profiles with healthcare services.

Another promising area for further research is healthcare process standardization and modularization. From a system point of view, modularization promises an approach to break up loosely linked healthcare services and arrange them into modules that can be performed rather independently. With modular healthcare processes, patients can have better-coordinated care by flexibly combining multiple modules that suit his/her conditions. Further study is needed to develop a rigorous approach to define and identify process modules, as well as methods for process configuration.

5.2. Consumer-Driven Health Economics

The complicated payment structure in the current healthcare system muddles the incentives for patients to save costs, and for care providers to seek the most cost-effective treatments. The concept of mass customization is to let consumers (i.e., patients) and the associated market force encourage competition for the best healthcare services and lowest costs. By putting purchasing power in the hands of the consumer, consumer-driven healthcare is becoming a new way to control health benefit expenses and engage patients in the healthcare delivery process.

To enable mass customization of healthcare services, further research is needed on health insurance plan design. A frontier of research is the design of insurance plans that are based on "health outcomes" instead of "medical expenses or fees". Although health plans with features like "co-payment" can deter the abuse of health insurance to some extent, a better design of health plans that encourage a healthier living style provides stronger incentives for people to prevent illness in the first place. A second issue concerning health insurance is the compatibility of plans among different insurance providers. Currently, most of the insurance plans are "one size for all" and people do not have meaningful choices. It would be interesting to investigate the possibility of designing health plan standards, so that different health plans can be easily compared and people are able to select the ones that fit with their specific conditions and needs.

5.3. System Integration and Service Coordination

To enable mass customization of healthcare services, the healthcare delivery system needs to be flexible in responding to different cases, while each healthcare facility in the system needs to be focused and specialized to achieve high efficiency. A specific research question arises regarding patient transition through the healthcare system. Current healthcare delivery systems are established as isolated departments for the purpose of maximizing efficiencies; customization of healthcare services requires viewing, and thinking of, the system from an individual patient's point of view. Thus, a smooth transition across multiple healthcare facilities, such as from a hospital to a community hospital or to a nursing home, is critical to enable mass customization of healthcare services. Future research is needed to

study the use of appropriate models, protocols, and contracts to ensure system integration and service coordination.

5.4. Enabling Technologies

New technologies are needed to support the delivery of customized healthcare services on a mass scale with high efficiency [123]. Among a large variety of technologies that are on the horizon, this paper suggests the following three technological fronts for future research.

The first is research in medicine, especially evidence-based medicine and personal medicine. A primary reason for the lack of efficiency in healthcare service delivery is its inherent variability, which makes it difficult to standardize the treatment procedure. A deeper understanding of medical science and continued development in technologies like personal medicine will provide a foundation to develop treatments that are customized to individual patient needs with high efficiency and high confidence. In recent years, research on integrating genetics and genomics into evidence-based medicine has been developed. Take EGAPP (Evaluation of Genomic Applications in Practice and Prevention) as an example, which is from the Centers for Disease Control and Prevention in the USA. It seeks to establish an evidence-based process for assessing genetic tests and other applications of genomic technology as these procedures transition from research to clinical and public health practice [124].

A second area for future research is health informatics. The gist of mass customization of healthcare services is to actively involve individual patients in the process of health service delivery. To get customized healthcare, patients need to make more decisions regarding their own personal health. The quality of their decision-making is vital for the success of mass customization of healthcare services. However, patients are generally not experts in healthcare and they may also be hampered in decision making because of illness. Consumer health informatics has made tremendous progress in terms of providing information regarding different healthcare services. For example, ambient intelligence (AmI) is used to provide personalized services by tailoring its reactions to the environment and user needs [125]. However, health informatics has been limited to information provision and patient education. Future research is needed to provide decision support and self-health management.

The third area for future research is on medical devices, especially decentralized diagnostic, testing, and monitoring devices. Medical equipment has traditionally been concentrated in large facilities, hospitals in particular. Given the high cost of these devices, the objective has been focused on high utilization. With the emergence of medical devices that are becoming increasingly small, mobile, and cheap, many healthcare services can be moved to other medical facilities, like nursing homes or individual households. For example, as an At-Home diagnostic monitor device, the FreeStyle Libre System (Abbott Diabetes Care, Witney, Oxon, UK) is used for glucose measuring. These devices can better involve individual patients in the provision of healthcare services.

6. Conclusions

Mass customization, as a proven strategy to deliver customized products with high efficiency and low cost in manufacturing, promises a new framework for healthcare delivery system redesign. Via an extensive review of the literature, this paper provides a synthesis of research that is most relevant to mass customization of healthcare services. The nature of healthcare is discussed relative to that of manufacturing, and the structure of a healthcare delivery system is discussed in comparison to that of a manufacturing system. Although healthcare, being a service system, stands in contrast to manufacturing in many aspects, there are fundamental similarities, in terms of value creation and delivery. This provided is a theoretical foundation for applying mass customization for healthcare service delivery.

This paper conducts an extensive review of the literature in multiple disciplines that are related to mass customization of healthcare services. On the medical front, the development in evidence-based medicine and personalized medicine promises to establish a

scientific foundation for the standardization of medical treatment, which will demystify the traditional concept of “medicine as an art” and make it possible to provide services for individual patients with high accuracy and confidence. On the information technology front, the development in consumer health informatics greatly reduces the information asymmetry between patients and physicians, making it possible for individual patients to participate in healthcare service delivery. On the health economics front, recent development in consumer-driven healthcare promises to put patients in charge of healthcare and to align patients’ economic incentives with their decisions regarding healthcare service consumption. At the system level, there has been progress in research towards developing an integrated healthcare delivery system, which is highly flexible in response to different cases, while being highly efficient with focused value-adding processes. In general, there has been growing research, in a wide range of fields, which is contributing towards mass customization of healthcare services.

Although mass customization will not be a universal framework for all healthcare service delivery, it provides a promising framework for redesigning the healthcare delivery system. We envision a future where patients can acquire healthcare services in much the same way as we purchase a Dell computer today. However, the concept of mass customization is still new in the context of healthcare, and it has not attracted sufficient attention nor the attention that it deserves. This paper suggests a number of areas for future research, including healthcare process redesign, consumer-driven health economics, healthcare system integration and coordination, and the development of enabling technologies. In conclusion, mass customization offers a promising framework to redesign the healthcare delivery system, and this paper provides a point of departure for further investigation and debate that will further drive the movement towards mass customization of healthcare services.

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