Using Feedback Systems Thinking to Explore Theories of Digital Business for Medtech Companies

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Abstract The rapid innovation of digital technologies poses a significant challenge to the healthcare sector. Digital technologies are transforming stakeholder relationships among established industry actors, including those of manufacturers, hospitals, and patients. To be ahead of competitors and to maintain profitability, medical device technology manufacturers (medtech companies) are urged to shift their business focus from product to customer excellence and thus invest in service offerings, focusing on the costs of alternative value delivery and patient outcomes. Such investments require a systemic and holistic understanding of how these changes in strategy affect the external and internal competitive environment. In this chapter, we propose the use of feedback systems thinking to explore the intended and unintended consequences of shifts in strategy, from sequential value chains to platform-oriented thinking. Taking the perspective of a medtech company in the value chain, we highlight challenges arising from hidden limits to growth that prevent the realization of intended achievements. Based on this, we develop hypotheses for the intended and unintended consequences of investing in digital service offerings. We conclude with a discussion of how systems thinking and modeling can support digital strategy development.

Keywords Digital transformation · Systems thinking · Systems archetypes Business model · Theory of business · Digital service strategy · Platform business · Healthcare · Medtech

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1 Introduction

Digital disruption is everywhere, and seems to be inevitable—a cliché that is regularly propagated in the media. Indeed, many industries have recently seen major shifts in competitive forces fueled by digitalization. The taxi industry and the hotel sector (viz., Uber and Airbnb) are often-discussed examples of the disruptive effects of digital technologies on businesses. However, while not all industries have experienced the same degree of disruption, the unreflective use and application of new digital technologies can have undesirable consequences. These may jeopardize or undermine the success of a business. Thus, in contrast to the uncritical optimism of technology evangelists and futurists, we agree with (Vermeulen 2017), who argues that some of the most common beliefs about the effect of digitalization on various industries have been "oversimplified, misunderstood, or misapplied".

Although the healthcare sector is slow to adopt digital technologies (Parente 2000; Wickramasinghe et al. 2005), changing stakeholder expectations and economic pressure are strong drivers of change. In addition, technology evangelists keep propagating digital technologies as saviors for these challenges. However, this stance neglects the dual role of digital technologies in organizational change. Such technologies can lock in processes as well as they can change them (Davies and Mitchell 1994; Easterbrook 2014; Peppard and Ward 2016). Thus, relying on dated approaches to the introduction of digital technologies for the transformation of organizations—for example, big bang implementations of new technology artifacts—is of no help for managing the messy, emergent process of a complex endeavor such as revising the business logics in an industry on the move (Weerakkody et al. 2011).

Feedback systems thinking offers an alternative approach. Systems thinking and modeling tools permit the analysis of potential consequences through the development of "micro-worlds" (Sterman 2001). These permit the operationalization of the "theory of business", our mental model of how a business works, to identify interactions between business models and interventions through the use of digital technologies (Drucker 1994; von Kutzschenbach and Brønn 2017). Such models capture essential causal relationships of planned transformation endeavors and enable the systematic evaluation of alternative approaches to technology implementation.

In this chapter, we propose the application of feedback systems thinking to the context of digital transformation. To this end, we have developed a case example which illustrates a medical device technology manufacturer (medtech company) that is planning to revise its strategic position. Consisting of more than a revision of its product portfolio, the change initiative is intended to transform the role of the company in the value chain. The development of this case example is based on interviews with managers of the company's leadership team. Applying a feedback systems approach, we develop hypotheses regarding the intended and unintended consequences of deploying innovative digital technologies for new service offerings in the healthcare industry.

To present the approach, we split the chapter into five sections. In the second section, we discuss the effect of digital technologies on the value chain. In the third

section, we highlight the characteristics of a feedback systems perspective on digital transformation and its application to healthcare value chain. Based on the case example, the fourth section illustrates the potential of the feedback systems approach for the revision of theories related to the intended strategic change of the medtech business. This section further describes the intended and unintended implications of investments in digital service offerings for the role of a medtech company in the value chain. We conclude this chapter with a section reflecting on the strategic thinking required for a successful digital transformation of medtech companies and provide ideas for future research.

2 From Sequential Value Chains to Platform Businesses

Digital business transformation is a major challenge for all organizations, particularly in the healthcare industry (Bohlin et al. 2014). One reason for this is, as a long-serving chief physician of a major hospital puts it, the "…*remarkable IT-technophobia of healthcare organizations*". However, recent changes in consumer behavior and cost pressure on healthcare providers are forcing the industry to rethink the traditional value delivery model (van Amersfoort et al. 2014; McKinsey and Company 2017). While publicly-funded players such as many hospitals can afford a defensive position, this is a major issue for medtech companies that have recently experienced considerable pressure on profitability and growth, the latter substantially leveling off from 11% to 4% after 2008 (Belcredi et al. 2016). Thus, medtech companies in particular are being forced to rethink their business models for identifying emergent growth opportunities.

The traditional and currently dominant value chain in the healthcare industry, from the perspective of a medtech company, is sequential (i.e. a pipeline). In this simplified view, medtech companies deliver their goods to hospitals, who use them on the end user, the patients. The flow of goods is unidirectional. Hospitals serve as the connecting element between the device suppliers and the patients, who are the ultimate customers in the value chain (see Fig. 1). Due to system boundaries, the visibility of actions and interactions among players in the value chain is very limited for each entity. This is further restricted fragmented flows of information.

The emergence of innovative digital technologies such as mobile applications, cloud infrastructures, social networks, etc., promote the transformation of the value chain. Such technologies permit the revision of stakeholder relationships to create a more networked structure. Goods are no longer just physical, but can be digitally enhanced or are purely digital (e.g. information services, knowledge exchange, data provision etc.). Furthermore, information is becoming a strategic resource. Through such technologies and the accordingly increasing interconnectedness of actors, medtech companies and other stakeholders in the value chain may directly engage with patients, for example through digital services platforms. However, lack of standardization in processes, lack of (digital) competencies, and absent relational thinking in the value chain, obstruct the opportunity for medtech companies to shift

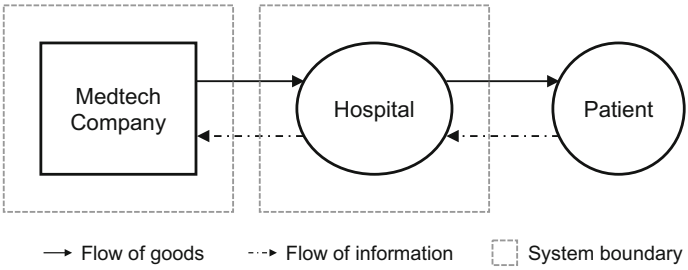

Fig. 1 Healthcare as a sequential value chain

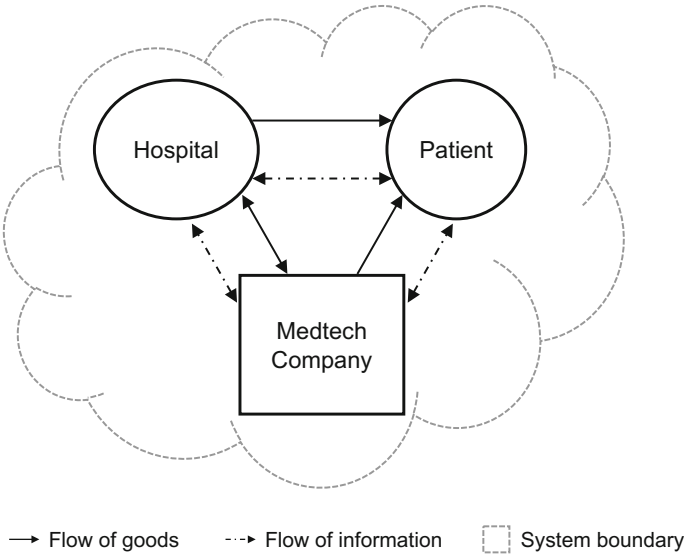

Fig. 2 Healthcare as a platform business

into the role of a network-based mediator (Andal-Ancion et al. 2003) (see Fig. 2). Such a platform business strategy crucially relies on strategic alliances and partnerships with new and existing players in a tangle of complex relationships among participants of the healthcare sector—a so-called ecosystem.

The shift from pipeline firms (sequential value chains) to platform businesses with ecosystems redefines the boundaries of the established business environment (van Alstyne et al. 2016). A platform thus denotes two-sided or multi-sided markets where multiple stakeholders (e.g. companies or other industry actors) with cross-side network externalities can interact (Eisenmann et al. 2006; Rochet and Tirole 2003). All participants in a platform setup can incur costs and accumulate revenue. For platform businesses, the focus shifts from delivering one product to one type of buyer towards relationships and interactions—the exchange of value within the ecosystem. Therefore, the participants must deal with more pluralistic, complex and

unstable environments. This is also because actors from outside the industry, e.g. from the information technology sector or the food industry, perceive growth possibilities in healthcare and are entering the market (Keys and Mainight 2010).

To take advantage of these trends, managers in medtech companies must rethink their "theory of business" (Drucker 1994). Those theories represent the organization's managerial understanding of "how things get done" (Osterwalder and Pigneur 2010), that is their mental model of how the business works. However, digital business transformation initiatives are cost intensive and uncertain. Increasing interconnectedness and the accelerating rate of change drive complexity, both within and across organizational boundaries (Billio et al. 2012; Kurzweil 2004). Thus, feedback systems thinking can help to create and analyze such a shared understanding of a business model's logic and its changes induced by digital business transformation initiatives.

3 A Feedback Systems Perspective on the Changing Healthcare Value Chain

The feedback perspective is a central element of systems thinking and modeling (Sterman 2000). It is best understood by comparing what is seen to be the "standard" approach to engaging with problems. The standard approach focuses on specific events that occur as a consequence of a problem-solving process. Decision makers compare the observations of these events with the desired situation. Where there is a discrepancy, a decision and the appropriate action is taken to minimize the deviation. The action and subsequent results conclude the decision-making process (see Fig. 3). If required, the next situation is then addressed. The main characteristics of this way of thinking are that it is linear and event-driven. There is usually no attempt to develop an operational explanation of the causes of the discrepancies. Such a way of thinking is particularly problematic in an environment where dynamic processes follow exponential developments, e.g. in networks (de Langhe et al. 2017; Senge 2006).

An alternative to the focus on events is the focus on feedback effects. Therein, the decision process recognizes the inherent dynamics of the situation, including the

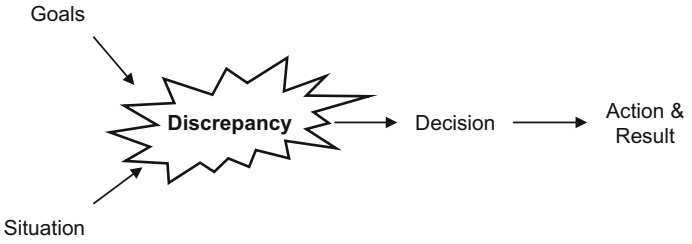

Fig. 3 Event-oriented world view (Adapted from Sterman 2000)

influence of actions taken in the past on the current situation. These, in turn, will influence future decisions. Additionally, this mode of thinking acknowledges the presence of other stakeholders and decision-makers who may have different goals and actions than the focal agent. A key aspect of this perspective is that it recognizes environmental impacts, meaning that one agent's actions to improve his/her situation affects another agent's ability to achieve his/her goals. This also includes the incorporation of unintended side effects on intended actions. Such effects influence the decision environment but often find no consideration in the mental decision models of individual actors. The presence of feedback structures implies that inputs are no longer independent of their outputs (Fowler 2003) (see Fig. 4).

Another characteristic of complex systems is the delay between cause and effect. Delays are inherent in organizational processes because responses to specific actions usually take a significant amount of time (Chen and MacMillan 1992; Larsen and Lomi 1999; Lomi et al. 2010). Consequently, the behavior of complex systems stands in contrast to open-loop, linear, sequential systems, and challenges traditional methods of analysis in which the independence, linearity, and strict exogeneity of influential factors are assumed.

Feedback systems thinking is a discipline that adopts a holistic perspective on complex organizational systems. The general approach is based on the system dynamics methodology that was initially developed by Jay W. Forrester at the Massachusetts Institute of Technology (MIT), USA, in the late 1950s. A systems thinking based analysis takes a step back from the level of single events and attempts to develop structural explanations of system behavior. Causal loop diagrams (CLDs) are a popular means of describing feedback loop systems. The core building blocks of CLDs are variables and causal relationships between them (see Fig. 5).

A causal loop diagram represents a feedback system. The loop blurs the distinction between the driver and the driven, between cause and effect, because, as time

Fig. 4 Feedback-oriented world view (Adapted from Sterman 2000)

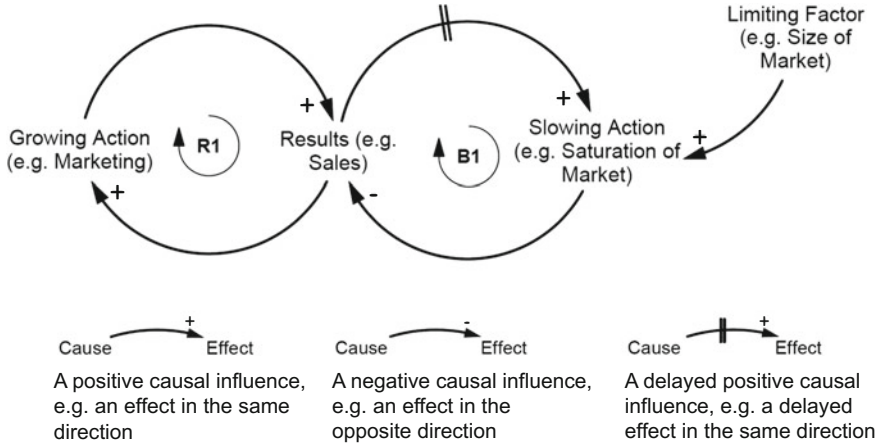

Fig. 5 Generic example of a causal loop diagram

progresses, each variable plays both roles. Taken together, the loops show overall systems behavior. Two types of feedback loops can be distinguished: positive or reinforcing (indicated by an "R" sign), negative or balancing (indicated by a "B" sign). Through identifying and mapping the causal linkages between variables, CLDs are representations of a modeler's understanding of systemic structures. The links shown by the arrows imply causal relationships between the different variables. This convention can express all causal relationships between and among variables of all kind. Variables cause change in other variables in two directions: "positive" (same direction, "+") or "negative" (opposite direction, "−"). For example, *Growing Action* in Fig. 5 is expected to increase (+) *Results*, and vice versa. Over time, however, as increasing *Results* is expected to increase (+) *Slowing Action,* which is expected to decrease (−) *Results* again. Time delays between causes and effects are marked with an "II" sign.

CLDs can be used to reveal managers' understanding of how a delineated system is designed and how it behaves. CLDs help to communicate and align the understanding of a person's or group's "theory of business". However, no model is ever complete, as each is an abstraction of reality, a reflection of the mental models of the people involved (Sterman 2002).

Recurring systemic structures responsible for generic patterns of behavior over time can be described as systems archetypes (Senge 2006; Wolstenholme 2003). Senge (2006, p. 93) describes them as follows: "If reinforcing and balancing feedback and delays are like the nouns and verbs of systems thinking, then the systems archetypes are analogous to basic sentences or simple stories that get retold again and again. …As we learn how to recognize more and more of these kinds of archetypes, it becomes possible for us to see more and more places where there is leverage in facing difficult challenges, and to explain these opportunities to others." Thus, systems archetypes represent a thinking tool whose major purpose

is to increase understanding of complex, dynamical systems or situations, and share insights about how the system in question works.

Wolstenholme (2003, p. 11) identified a set of four generic archetypes, each composed of two feedback loops:

- "*Underachievement*, where intended achievement fails to be realised;
- *Out of control*, where intended control fails to be realised;
- *Relative achievement*, where achievement is only gained at the expense of another [part of the system];
- *Relative control*, where control is only gained at the expense of others [stakeholders' benefits]."

We can distinguish problem archetypes from solution archetypes. A problem archetype is one whose net behavior is far from that intended by the people creating the system (see Fig. 5). The idea of a two-loop system archetype with problem behavior leads to the idea of a solution archetype to minimize side effects (Wolstenholme 2003). In this example, a significant problem for the system's long-term growth is market size. The CLD supports the identification of this limitation and shifts the attention from the intended consequences of "growing action" to "slowing action" and the according limitation. Managerial measures can be derived from this, e.g. the consideration of actions (introducing new "solution" feedback loops) to increase market size.

Digital transformation initiatives are an illustrative example of decision-making situations with multiple stakeholders and agents who are closely connected. A decision by one stakeholder will propagate through the system, affecting others, often with unknown consequences.

The simplified healthcare system we present in Fig. 1 has three major stakeholder groups—the medtech equipment supplier, the hospital and the patient. In their engagement with the value system, each stakeholder has dramatically different action sets and goals, many of which may conflict with the goals of the others. A successful transformation endeavor must take these issues into consideration. It can be speculated that a high percentage of unsuccessful transformation initiatives results from not recognizing the complexity of the change process (Flyvbjerg and Budzier 2011). From a feedback systems perspective, problem archetypes are pervasive in digital transformation endeavors.

4 Case Example—The Underachievement of DigitalMedTech

To illustrate the potential of system dynamics in the revision of theories of business, we have applied a feedback systems thinking approach to a medtech company. We derive our insights in part from interviews with executives in a major global medtech company which we call "DigitalMedTech" to preserve anonymity.

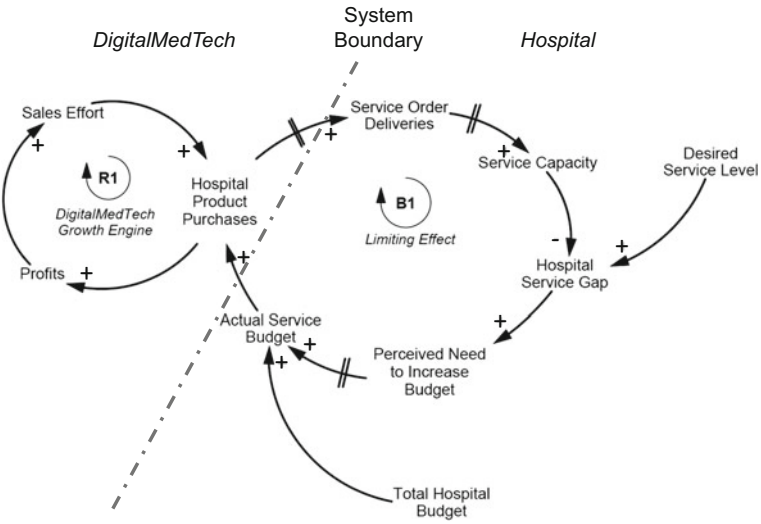

Fig. 6 DigitalMedTech problem archetype

We argue that with their current theory of business, DigitalMedTech faces an *underachievement* problem, which can be illustrated using a problem archetype. They focus primarily on the sale of physical goods. Increasing sales efforts result in higher hospital product purchases that, in turn, finance continued profit growth. We describe such a theory of business for DigitalMedTech in Fig. 6. Loop "R1" describes the growth engine. The hospital is a stakeholder in this process that has its own goals and limitations. A continuing increase in "*Hospital Product Purchases*" leads to an increase in the "*Service Capacity*" of the hospital. However, over time, the system will encounter a balancing process (Loop "B2") as the limit of the system is approached. This causes a delayed underachievement of the main objective over time (see Fig. 6).

A sequential value chain perspective strengthens the constraints imposed by existing system boundaries. The problem archetype in Fig. 6 includes a system boundary that "hides" the unintended consequences from the "view" of DigitalMedTech. Thus, upon realizing decreasing "*Hospital Product Purchases*", managers can only invest in the enhancement of turnover, unaware that the amount of healthcare service spending depends on the "*Hospital Service Gap*". In this model, the "*Hospital Service Gap*" results from the discrepancy between "*Desired Service Level*" and actual "*Service Capacity*". The level of discrepancy induces the pressure for change. This translates into specific action to improve the situation, i.e. closing the gap between the actual and the desired states. Thus, an increase in hospital "*Service Capacity*" leads to a decrease in the "*Hospital Service Gap*" which causes a decrease in "*Hospital Product Purchases*" over time due to a limited "*Actual Service Budget*". This ultimately reduces service purchases which adversely affects the growth model of DigitalMedTech.

A possible way out of this underachievement for DigitalMedTech is to break out of the isolated role in the value chain and to proactively manage its stakeholder relationships, introducing one or more "solution" feedback loops. Strategic partnerships could help DigitalMedTech to gain direct access to patients. Digital technologies, furthermore, could improve customer retention. Thus, value-based healthcare services (Foley et al. 2014), including digital services offerings such as patient education, patient engagement, operating room efficiency, rehab follow up, and outcome measurements, are a potential field of investment. The "solution" is to position DigitalMedTech to better understand customer needs (for hospitals as well as patients) and to help hospitals to optimize their process efficiencies for delivering better patient outcomes. Being able to extend its offerings by implementing digital services as described above permits DigitalMedTech to evolve its position to a more central role in the healthcare system.

Driving technology-enabled services in the healthcare system allows DigitalMedTech to offer added value to its strategic partners through capturing and comparing a variety of data from different companies (hospitals) as well as patients. This requires process standardization in order to enable comparability and digitalization for both DigitalMedTech and hospitals. The standardization of the processes, especially in the operating room (OR), enables benchmarking and thus further optimization which in turn will positively drive DigitalMedTech's sales. This has the dual effect of saving costs and improving the service capacity of hospitals.

In the next section, we describe what such a revised theory of business for DigitalMedTech could look like developing a solution archetype.

5 Digital Services Platform Business as Solution

On its way to extending the focus from product towards customer excellence, DigitalMedTech started an initiative investing in a digital patient platform and services. Based on Wolstenholme (2003) understanding of the solution archetype concept and on information gathered from interviews with representatives from DigitalMedTech's leadership team, we extended the "DigitalMedTech problem archetype" model (see Fig. 6) to a solution archetype. Thus, the mapping of the "solution links" results in two additional loops that enable the partnering hospitals to run their processes more efficiently, "R2: Efficiency Improvement Loop", and to improve patient engagement and outcomes, "R3: Quality Improvement Loop" (see Fig. 7).

"R2: Efficiency Improvement Loop": A higher investment in digital service increases the "*Degree of Process Standardization*" of healthcare processes which improves the "*Service Process Efficiency*", in particular OR efficiency. Thus, effective use of OR time is imperative for cost-efficient operations and close attention should be paid to practices that affect the efficiency of the OR. Standardizing processes and improving information increase transparency. Improving on-time starts and turnover time increases hospital production. Furthermore, reducing the cancellation rates helps to reduce unnecessary costs to OR use, and saves money which

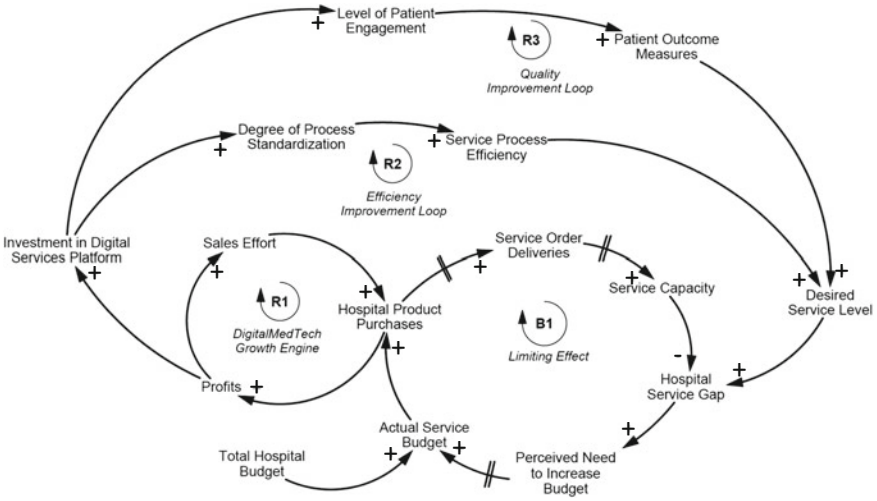

Fig. 7 DigitalMedTech solution archetype

would otherwise be spent on unnecessary setups, instrument sterilization, and supplies. Reducing cancellation rates and delays frees up availability in the OR schedule as well as maximizing OR use. Thus, improving "*Service Process Efficiency*" contributes to increase the "*Desired Service Level*".

"R3: Quality Improvement Loop": Today 45% of consumers search for health information on social media (van Amersfoort et al. 2014). Social media and mobile platforms are becoming increasingly important channels for consumers and provide a means to measure patient satisfaction to improve the quality of healthcare delivery (e.g. Porter 2009; Porter et al. 2016). Higher investments in digital service offerings lead to a higher "*Level of Patient Engagement*". Being able to leverage social media extensively to engage with consumers will help, firstly, to provide consumers with timely and relevant information, and secondly to improve feedback about patient satisfaction and service quality, thus improving the level of "*Patient Outcome Measures*". Improving the level of "*Patient Outcome Measures*" will increase the "*Desired Service Level*" of the hospital.

"*Investment in Digital Services Platform*" is a key element of a digital strategy for DigitalMedTech. At the same time, it will face unanticipated and potentially undesirable consequences. Providing services based on emerging digital technologies often fosters a lock-in effect that is difficult to disengage from. For DigitalMedTech this might be preferable, however, for hospitals it can impose constraints that could be seen as undesirable.

Such effects can be illustrated with balancing feedback loops added to the model. They can feed back to DigitalMedTech's growth engine (see Fig. 8). The two negative feedback loops (Loop "B2" and "B3") are driven by an "*Investment in Digital Services Platform*". This makes the hospital increasingly dependent on the knowledge and

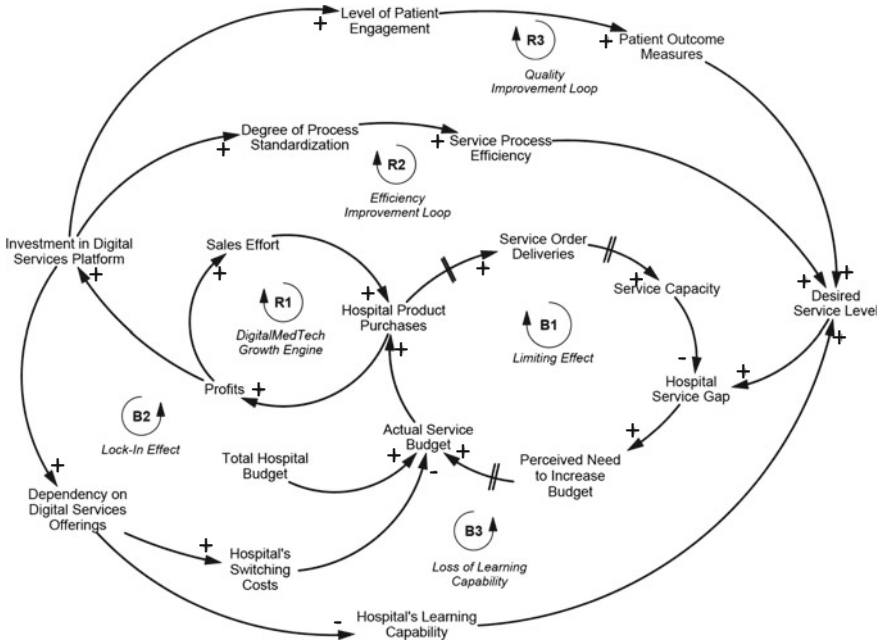

Fig. 8 Potential side effects of digital service strategy

technology of DigitalMedTech. First, loop "B2" shows the costs of being technically bound by increasing the "*Hospital's Switching Costs*" to another platform provider. This affects the hospital's budget, the "*Actual Service Budget*" because switching from established technology and connected services can be costly, and sometimes nearly impossible without starting from scratch. Second, loop "B3" is related to the limitations on the "*Hospital's Learning Capability*" by being bound to a single digital services supplier. Being locked-in makes it difficult for the hospital to invest in its own learning capability and to facilitate organizational learning, in particular double-loop learning (Argyris 1977). This can affect the "*Desired Service Level*" provided by the hospital. The "*Hospital Service Gap*" is the key driver in the hospital's budgeting process so this is an important relationship.

Feedback systems thinking enables the explication of theories of business (von Kutzschenbach and Brønn 2017). This makes them easier to evaluate and adapt. The tendency to focus on the desired outcome, and neglect or ignore the undesirable ones, is hazardous. Feedback systems thinking contributes to overcoming this effect by building models that can be explained, criticized, and modified by relevant stakeholders. An explicit model of the "theory of business" encourages active discussions of the critical assumptions underlying the current business model. In order to revise the model, the next steps will involve quantifying the variables and testing the assumptions in a simulation model. These steps allow the creation of a computer-based micro-world and a validation of the model.

6 Conclusion

Managers and organizations hesitate to engage in feedback systems thinking for problem solving. This is mainly because decision-makers operate under different and conflicting performance indicators in separate departments, teams, and functions. This fragmentation of the larger organization into smaller silo organizations in traditional value chains masks critical links and vital interdependencies amongst different actors with adversarial effects on the external and internal organizational environment.

The pace in today's organizations is so unrelenting that there is little room for managers to pause, reflect, and learn. Consequently, most organizations realize only small fractions of their potential (Forrester 1994). This is particularly striking in the context of digital transformation endeavors as consequences of such initiatives are nearly impossible to assess *ex ante*. Applying feedback systems thinking helps decision-makers to operationalize and communicate models for their "theory of business". Such an approach enables a better identification of interactions between the model and the digital intervention.

The DigitalMedTech case provides an illustrative example of industry players facing underachievement. Until now, they have barely been able to reap the potential benefits of emerging digital technologies. However, growing their business requires a shift from transactional, sequential value chains to a platform business. They would thereby aspire to act as trusted advisors to other healthcare providers such as hospitals and patients. A digital service platform using a systematic measurement of outcomes that mattered to patients would allow DigitalMedTech to provide value-based services for improving the healthcare delivery service with benchmarking and learning on a condition-by-condition basis. Driving such a digital transformation is a complex endeavor. We thus propose to use feedback systems thinking for the revision of theories of business.

We provide an extended causal loop model that can be used to develop a simulation model. This can enhance learning, provide deeper understanding and insights, and reveal inconsistencies and "blind spots" in policies and digital strategies. However, it is clear that the feedback systems thinking approach in managing digital transformation endeavors is only at its beginning. Further research is needed to connect feedback systems thinking and modeling to digital transformation, and demonstrate its potential benefits as a complementary tool for strategy development.

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