

# American Journal of Health Behavior

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# An Empirical Study on the Use of Digital Technologies to Achieve Cost-Effectiveness in Healthcare Management

Maryati Sutarno, Ph.D  
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**Objectives:** Healthcare cost reduction is one of the major challenges of the current era. This study was based on the general system theory-based view to assess the significance of sensing communication technologies and processing actuation technologies in improving healthcare quality, leading to cost reduction. Moreover, the contingent rule of healthcare supply chain management in enhancing the influence of improved quality on healthcare cost reduction was also empirically tested. **Methods:** The sample of the study comprised 337 middle and senior healthcare managers employed in various government and private hospitals and health institutions in Jakarta, Indonesia. The administrative departments of each hospital and health institution was visited to take their consent to conduct this survey at their clinical and non-clinical departments. The data collected was analyzed using SmartPLS ver. 4 software. **Results:** Results reveal a significant direct and indirect influence of sensing communication technologies and processing actuation technologies on achieving cost-effectiveness in the healthcare sector, in the presence of perceived quality improvement as a mediator. However, the strength of the associations varied and was based on highly reliable and familiar nature of sensing communication technologies compared to processing actuation technologies which were emerging and gaining popularity in recent years. **Conclusion:** Considering the healthcare cost as a critical factor based on limited resources in emerging economies, healthcare institutions/centers should use digital technologies to achieve cost-effectiveness for providing healthcare facilities in the industry 4.0 era.

**Keywords:** Sensing Communication Technologies; Processing Actuation Technologies; Perceived Quality Improvement; Healthcare Supply Chain Management

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Healthcare costs are referred to as expenditure incurred over the consumption of a resource with the primary objective of promoting, restoring, and maintaining health. Over the past few decades, healthcare costs have significantly increased worldwide. According to World Health Organization 2019, healthcare expenditure has grown faster than the entire global economy.<sup>1</sup> This further accounts for almost 10 percent of the global gross domestic product. WHO further reported a critical increasing trend in healthcare expenditure in emerging economies, with approximately 6% annual spending on health in developing economies compared to 4% in developed nations.<sup>2</sup> Several reasons have been attributed to the drastic increase

in healthcare and expenditure in developing nations including the increase in longevity of life. It is significant to note that approximately 65 percent of the worldwide population aged above 60 years belongs to emerging economies.<sup>3</sup> United Nations had reported in 2013 that this proportion is further expected to rise by around 79 percent by the end of 2050.<sup>4</sup>

Chronic illnesses, including neurological disorders, heart disease, and diabetes, have increased the cost of healthcare across masses.<sup>5</sup> As a result, technologies penetrated into the healthcare sector to facilitate the health care organizations to transform their layouts in hospital centers and patient-centered institutions, with a view to improving health outcomes.<sup>6</sup> On the other hand, regardless of the enormous benefits of

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digital technologies in terms of enhanced labor skills and associated capital expenditure, the adoption of these technologies has been the biggest challenge to health organizations.<sup>1,7</sup>

There is a dearth of consistent and reliable studies to present how digital technologies could lead to reduction of healthcare costs. Hence, based on such contradictory findings and limited results, the current study aimed at calling for further clinical and academic research to identify and examine the factors impacting healthcare cost reduction with improved quality to provide standard healthcare services to the masses.<sup>1,2,8</sup> To address this call and based on the utmost significance of digital technology penetration in the healthcare sector, the current study therefore chose sensing communication technologies and processing actuation technologies in Industry 4.0 to investigate their impact on reduced healthcare costs.

Sensing communication technologies present the Internet of Things, cloud computing, artificial intelligence, healthcare digital sensors, etc., and are widely used in the medical sector.<sup>9</sup> At the same time, actuators are the equipment that provide advanced flow control based on their dynamic abilities. Strong actuation technologies became mandatory in the healthcare sector to be cost-effective and efficient in performance.<sup>10</sup> In addition to the direct influence of sensing communication technologies and processing actuation technologies on reduced health costs, the current study also assessed the mediatory role of perceived quality improvement in the healthcare sector. Since systematically improved healthcare presents a high quality in the healthcare sector; quality improvement can be defined as a standardized structure and process, reducing variations and achieving desired outcomes following the patient's expectations in the healthcare system.<sup>11</sup> It also presents various factors that impact quality improvement in the healthcare sector linked with digital technologies.<sup>12,13</sup> This leads to understand how modern technologies in the healthcare system can help achieving cost-effectiveness.

A high quality healthcare system is always linked with cost reduction based on the competitive edge and the effective utilization of resources.<sup>14,15</sup> In addition to the direct and indirect association of various technological factors with reduced healthcare costs, past studies have also assessed the contingent impact of supply chain management in

the healthcare sector to transmit the significance of high quality in reducing healthcare costs. This can be further related to the fact that the supply chain is an important determinant of an organization's success and productivity.<sup>16</sup> Simultaneously, researchers have also reported supply chain management's positive association with economies of scale.<sup>17</sup>

Indonesia is a developing nation with a continuously enhanced demand for the healthcare sector with enhanced healthcare expenditure in the last few decades.<sup>18</sup> As per WHO, between 2000 and 2016, low- and middle-income nations witnessed an increase in per capita public spending in the healthcare sector ranging from 30-130 USD to 58-270 USD.<sup>1</sup> Following WHO, Indonesia's healthcare spending for 2019 was \$120, a 7.58 percent increase from 2018. Simultaneously, despite several favorable factors making Indonesia one of the best places to live, its healthcare system lacks international standards with many deficiencies.<sup>19</sup> Although there are several best-equipped public hospitals in Jakarta, unfortunately, none of them have global accreditation. On the other side, Indonesian hospitals are embracing digital technologies similar to other walks of life.<sup>20</sup> Hence, it is of timely importance to investigate the influence of these digital technologies on cost reduction of the healthcare system in Indonesia. Thus, establishing the General System Theory,<sup>21</sup> the current study aims to answer the following questions.

- To what extent are sensing communication technologies and processing actuation technologies vital to reduce healthcare costs?
- Does improved healthcare quality help to reduce healthcare costs?
- Does the improved healthcare quality mediate the association of sensing communication technologies and processing actuation technologies with healthcare cost reduction?
- Does healthcare supply chain management moderate the association of improved healthcare quality with reduced healthcare cost?

Hence, the current study aimed to assess the significant role of sensing communication technologies and processing actuation technologies in reducing healthcare costs in the context of a developing nation.

## LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

### The General System Theory

The current study has been conducted on the assumptions of the General System Theory<sup>21</sup> which asserts that displacement of a structure and forces produced within a system based on certain external influences determine the behavior of that system.<sup>22</sup> The theory postulates that various interdependent and interrelated elements conglomerate cohesively to form a system depending upon the environment of that system.<sup>23</sup> At the same time, the theory assumes the achievement of the goal in different ways with the help of a clear understanding of the alignments in the prevailing system.<sup>24</sup> In contrast, the authors' main goal in the current study is the achievement of cost-effectiveness in the healthcare sector. Hence, it is postulated that different technological advancements (sensing communication technologies and processing actuation technologies) in the healthcare sectors are considered important and help healthcare institutions to achieve their goal in the form of reduced healthcare costs.

### Sensing Communication Technologies, Processing Actuation Technologies, and Reduced Healthcare Cost

The technological revolution in industry 4.0 emerged as a promising solution to global challenges, including healthcare cost reduction.<sup>25</sup> Although, the integration of digital technologies into the healthcare system is not new, as most healthcare institutions started to record their medical documents and other patient's activities electronically in the 1920s.<sup>26</sup> However, paper records were still kept and used in most medical institutions until the 1960s. But after rapid technological advancements and innovations with the introduction of personal computers at the start of the 1980s, novel solutions to their healthcare system using digital technologies emerged.<sup>27</sup> Besides, sensing and communication technologies came into existence and resulted in improved service quality, optimization of cost, and expanded coverage and access to healthcare resources.<sup>28</sup>

Regarding the influence of digital technology integration in optimizing healthcare costs and expanding access and coverage, the research on healthcare cost reduction is inconclusive, with an uncertain effect of industrial 4.0 technological implementations on healthcare cost reduction.<sup>1</sup>

However, existing studies present the significance of healthcare technologies in bringing medical advances in processes with extended scope, quality, and range of the healthcare sector.<sup>8</sup> These functions can further be related to the cost-effectiveness of the healthcare sector.<sup>29</sup> Simultaneously research reports the significance of technological innovations in the Internet of Things, cloud computing, remote control monitoring, machine learning, and medical sensors in bringing cost-effectiveness to the healthcare sector.<sup>30</sup> However, to the best of the author's knowledge, literature is scarce regarding empirical testing of sensing communication technologies and processing actuation technologies facilitating reduced healthcare costs. Thus, to bridge this existing gap in the literature, the current study hypothesizes that:

*H1: a) Sensing communication technologies and b) processing actuation technologies significantly cause healthcare cost reduction.*

### Sensing Communication Technologies, Processing actuation Technologies, and Perceived Healthcare Quality Improvement

The sensing communication bundle comprises the digital technologies used for communicating and capturing data regarding the process, material or equipment, patients, etc..<sup>31</sup> At the same time, the processing actuation bundle comprises technologies that process such data and transform it into actual information using various mechanisms or software via controlling or moving a system.<sup>32</sup> Besides, research also shows that healthcare actuators help in the liquid handling process, moving off samples, and loading and unloading data during various necessary healthcare treatment stages.<sup>4</sup> Although, research reports that industry 4.0 healthcare digital technologies are an important predictor of healthcare cost reduction and enhanced quality.<sup>33</sup> However, very limited research is available regarding the impact of sensing communication and processing actuation technologies on healthcare quality improvement.<sup>1</sup> Therefore, the current study intends to bridge this existing gap in the healthcare literature and postulates that;

*H2: a) Sensing communication technologies and b) processing actuation technologies are positively linked with perceived healthcare quality improvement.*

### **Perceived Quality Improvement and Reduced Healthcare Cost**

A systematic improvement in care represents the quality improvement of the system.<sup>34</sup> Besides, quality improvement helps structure and standardize a system to enhance patient outcomes, achieve desirable reserves, and reduce variations in healthcare treatments.<sup>35</sup> Previously researchers have linked quality improvement in the healthcare system to achieving economies of scale, improved treatments, patient satisfaction, and doctor's efficiency.<sup>36,37</sup> Simultaneously, researchers have also considered the role of quality improvement in various organizations' productivity and cost-effectiveness and found significant results.<sup>38</sup> Applying similar results in the healthcare sector, the current study postulates that managers' and supervisors' perceptions of healthcare quality improvement are important predictors of reduced healthcare costs. Hence it is hypothesized that:

*H3: Perceived quality improvement is positively associated with reduced healthcare cost*

### **Perceived Quality Improvement as a Mediator**

In addition to the direct influence of sensory communication technologies and processing actuation technologies in bringing cost-effectiveness in the healthcare sector, the current study also analyzes the mediatory role of perceived quality improvement in transmitting the impact of modern healthcare technologies in the industry 4.0 era to make the healthcare system cost-effective. Technological intrusion in the healthcare system is positively linked with cost reduction.<sup>4,27</sup> Researchers believe that when the quality of the healthcare system is improved using various technologies, bringing ease of access to the healthcare system by the masses, the healthcare system's cost is ultimately reduced.<sup>37</sup> Likewise, Bhatia<sup>29</sup> asserted the significance of improved quality in terms of patients' dealing, processing medications, add emergency treatments in making the healthcare system cost-effective. Besides, sensing communication technologies and healthcare processing actuators are considered efficient systems to enhance the effectiveness of healthcare systems with low processing and communication cost.<sup>1</sup> This effectiveness of the healthcare system can further be related to the

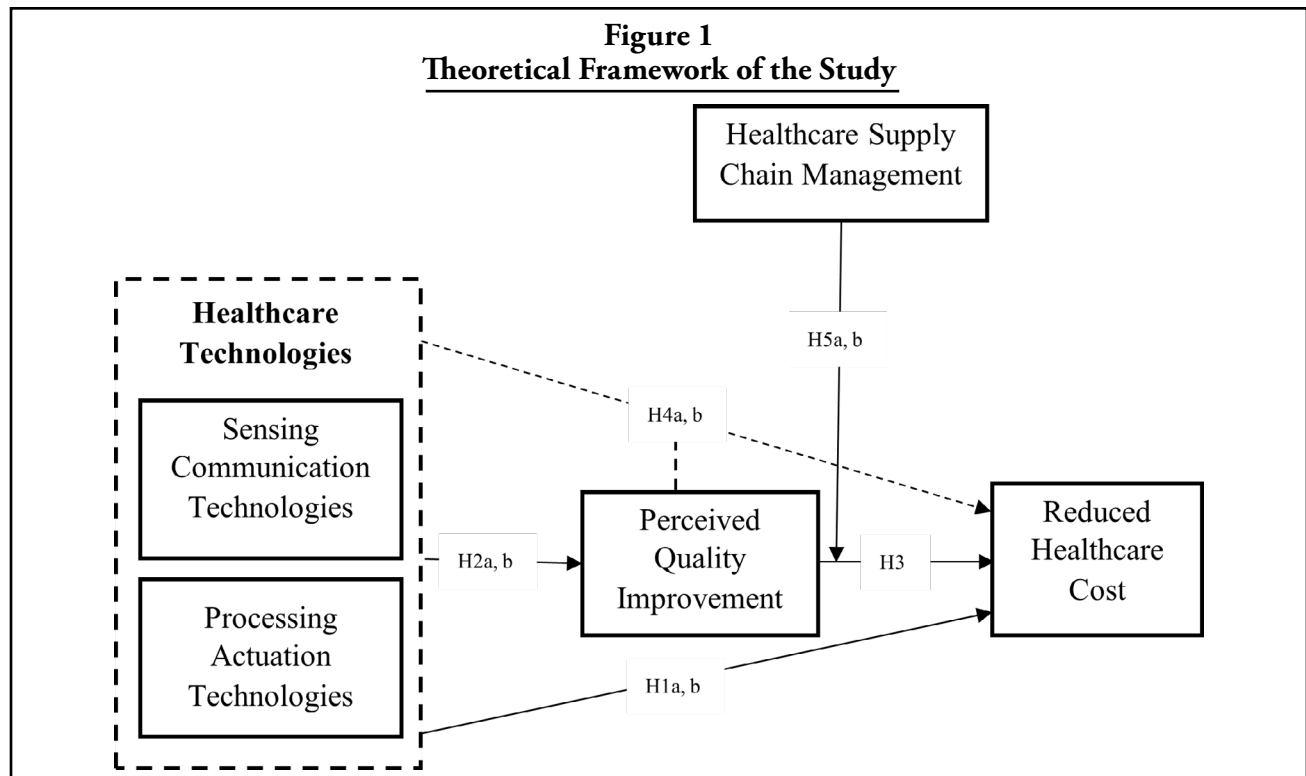
improved quality that leads to the reduction of cost based on achieving economies of scale. Hence it is hypothesized that:

*H4: Perceived quality improvement mediates the association of a) sensing communication technologies and b) processing actuation technologies with healthcare cost reduction.*

### **Healthcare supply Chain Management as a Moderator**

Healthcare supply chain management stakeholders apply different strategies to economically manage the healthcare supply chain. Regarding managing the supply chain, two important approaches, including dynamic and static complexity inventory, are considered important.<sup>39</sup> The static complexity perspective relies on reducing the number of suppliers, products, distribution, and processing, which might further lead to a considerable reduction in supply chain management costs.<sup>40</sup> However, this may lead to disruption risks for the supply chain. Besides, the dynamic complexity perspective is often applied in the healthcare supply chain sector<sup>41</sup> if the Enterprise Resource Planning software, i.e., Epic system corporation, is applied to enhance the collaboration with healthcare supply chain participants, i.e., patients, distributors, purchasing group organizations, and producers.<sup>33</sup> This integration of the resource planning software in the healthcare supply chain management process further helps to reduce the overall healthcare cost. Previously researchers have considered the significant impact of using warehouse management systems and radio frequency identification technologies in supply chain management to reduce cost.<sup>42</sup> In contrast, the current study has been established in the general system-based view. It aims to examine the interactive effect of healthcare supply chain management with improved healthcare to effectively reduce healthcare costs, more specifically in a developing nation context. Hence it is hypothesized that:

*H5: Healthcare supply chain management moderates the association of a) sensing communication technologies and b) processing actuation technologies with reduced healthcare quality such that the association is stronger in the case of a highly managed healthcare supply chain.*



## RESEARCH METHODOLOGY

### Participants and Procedures

An empirical approach applying survey methodology was used to address the study objectives based on its high level of representativeness, standardized stimulus potential, statistical significance, and cost-effectiveness.<sup>43</sup> The researchers followed 4 steps using this methodology, including the data collection regarding the respondents' characteristics, the adaption of study measures and development of the instrument, assessing the validity and reliability of the study constructs, and conducting data analysis to examine the hypothesized relationships. For the data collection, the study researchers visited various health institutions, including government and private hospitals in Jakarta, Indonesia, following the methodology used by Tortorella et al.<sup>1</sup> They contacted the administrative departments of the hospitals to take their consent to survey the middle and senior managers of leading clinical and non-clinical departments.

Moreover, before selecting the study participants author verified the presence of digital transformation and modern technologies in the hospital. After taking the formal consent, the researchers approached the study participants. They requested them to voluntarily participate in this survey after explaining the purpose

and significance of the study in the healthcare sector. Those willing to voluntarily participate in the survey were handed over the questionnaire. Data were collected from January 2022 to September 2022. A final sample of 337 respondents from 20 hospitals was obtained. Among these 20 hospitals, 11 belonged to the private sector, and nine were from the public sector. Besides, 59.3 percent of the participants were male, and 41.7 percent were females. The participants' ages ranged from 25 to 59 years (Mean=37 years; SD=7.8). Most of the participants were either coordinators or supervisors (85.3 percent). They had a minimum experience of 2.5 years and a maximum experience of 36 years. Finally, 62.4 percent of the respondents belonged to the clinical department, compared to 38.6 percent belonging to non-clinical departments.

### Measures of the Study

A survey questionnaire consisting of 17 items related to study constructs was used to collect data. Sensing-communication technologies were measured with five items adapted from Tortorella et al.<sup>4</sup> Processing actuation technologies were measured with four items adapted from Tortorella et al.<sup>1</sup> Moreover, to measure the perceived quality improvement of the healthcare system,

three items adapted from Tortorella et al.<sup>1</sup> were used. Simultaneously, to measure healthcare cost reduction, two items were adapted from Patel et al.<sup>44</sup> Finally, healthcare supply chain management was measured with three items adapted from Essila<sup>33</sup>. All the study constructs were measured on a “five-point Likert scale ranging from 1=strongly disagree to 5=strongly agree.

**DATA ANALYSIS AND RESULTS**

**Measurement Model**

SmartPLS ver. 4 software was used for analyses of the collected data. A series of simulation analysis results showed the significant impact of hospital ownership on healthcare cost reduction; hence,

hospital ownership was controlled during the regression analysis. Moreover, to establish the reliabilities and validities of the study constructs, their psychometric properties were assessed. For that purpose, the values of Cronbach’s  $\alpha$  (CA) and Composite Reliability (CR) were recorded.<sup>45,46</sup> The results, as shown in Table 1, present that all the values of CA and CR were greater than threshold values, i.e., 0.70, reflecting the validity and reliability of the collected data. Moreover, the factor loadings of all the study measures were greater than 0.70, and the Average Variance Extracted (AVE) was above 0.50, as recommended by scholars as indicators of measures reliability.<sup>47,48</sup> The factor loadings are also presented in Figure 2.

Constructs/Indicators	Factor Loadings					AVE	CR	CA
	1	2	3	4	5			
<b>Sensing-Communication Technologies</b>						0.568	0.868	0.801
SCT1	0.720							
SCT2	0.719							
SCT3	0.776							
SCT4	0.791							
SCT5	0.761							
<b>Processing-Actuation Technologies</b>						0.566	0.839	0.758
PAT1		0.762						
PAT2		0.706						
PAT3		0.793						
PAT4		0.747						
<b>Perceived Quality Improvement</b>						0.651	0.848	0.767
PQI1			0.793					
PQI2			0.790					
PQI3			0.836					
<b>Reduced Healthcare Cost</b>						0.580	0.734	0.712
HCR1				0.749				
HCR2				0.774				
<b>Healthcare Supply Chain Management</b>						0.549	0.785	0.735
HSCM1					0.754			
HSCM2					0.741			
HSCM3					0.727			

Note.  
CR, composite reliability; CA, Cronbach Alpha; AVE, average variance extracted.  
SCT=Sensing-Communication Technologies; PAT=Processing-Actuation Technologies; PQI=Perceived Quality Improvement; HCR=Reduced Healthcare Cost; HSCM=Healthcare Supply Chain Management

Additionally, to establish the discriminant validity among all the study variables, the current study considered the values of Heterotrait-Monotrait (HTMT) as one of the most reliable measures to address multi-collinearity issues among the study variables.<sup>45,49</sup> The findings showed that HTMT values for the association of all variables were less than 0.90 (a threshold value suggested by scholars).<sup>47,50</sup> Thus, based on these less correlational values below 0.90, it is concluded that there is no issue of multi-collinearity among the study constructs.

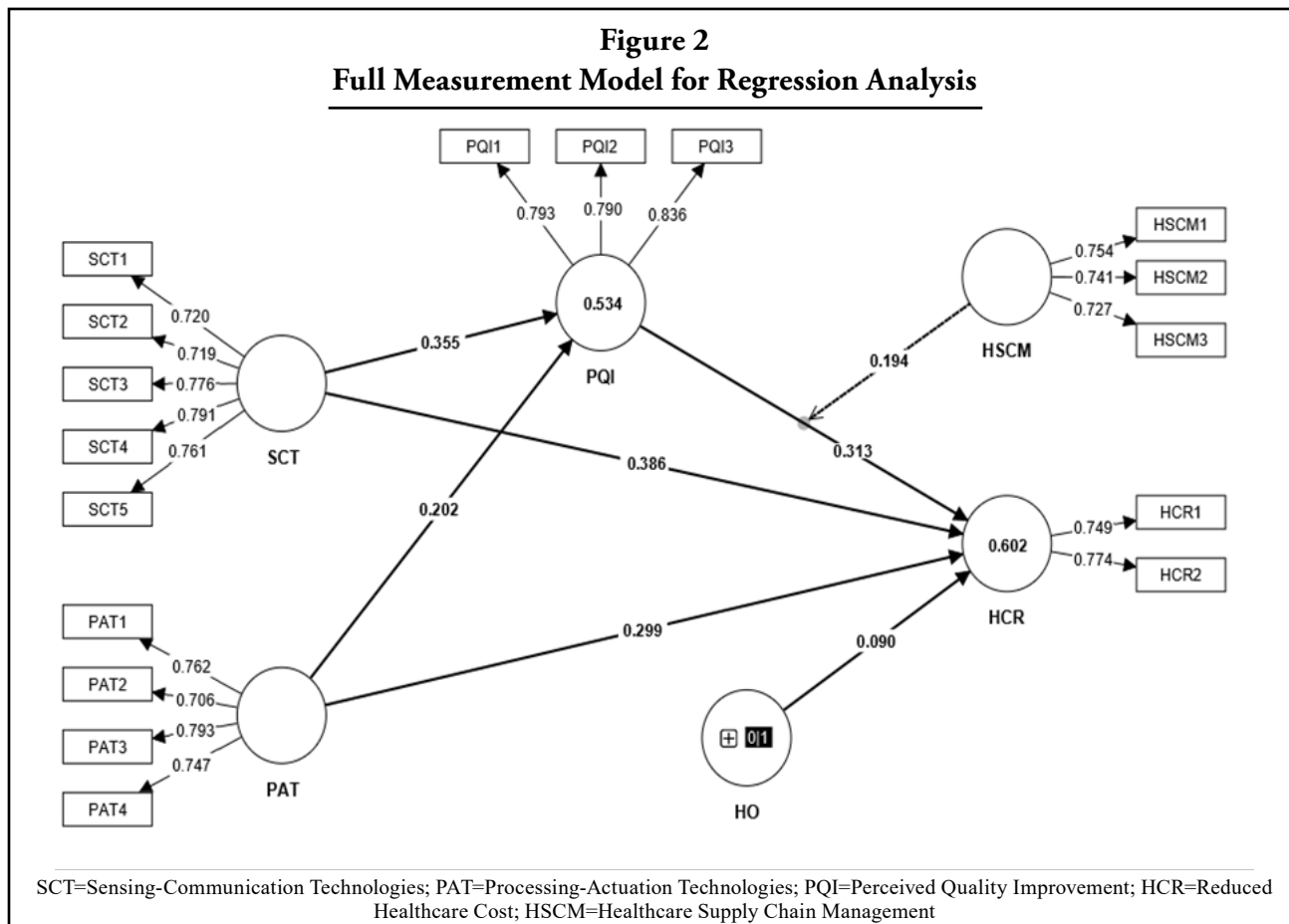
Constructs	Mean	STD	1	2	3	4	5
SCT	4.04	0.90	<b>0.753</b>				
PAT	3.88	1.08	0.503	<b>0.752</b>			
PQI	4.13	0.97	0.489	0.566	<b>0.806</b>		
HCR	3.81	1.11	0.544	0.493	0.495	<b>0.761</b>	
HSCM	3.95	1.03	0.513	0.435	0.504	0.544	<b>0.740</b>

Note.  
The square roots of AVEs of the constructs are shown in bold in diagonal.  
SCT=Sensing-Communication Technologies; PAT=Processing-Actuation Technologies; PQI=Perceived Quality Improvement; HCR=Reduced Healthcare Cost; HSCM=Healthcare Supply Chain Management

**Structural Model**

For the authentication of the hypothesized relationships, the current study used SmartPLS v.4 software to conduct the regression analysis. Moreover,

to report the strength of the hypothesized associations,  $\beta$ -coefficient,  $p$ -value, and  $t$ -value were calculated. Simultaneously, the Coefficient of Determination ( $R^2$ ) was assessed to report the overall model fitness.



**Hypotheses Testing**

Results show that sensing-communication technologies ( $\beta=0.386^{***}$ ,  $t=7.751$ ) and processing-actuation technologies ( $\beta=0.299^{***}$ ,  $t=6.786$ ) have a positive impact on health care cost reduction. Similarly, results showed that sensing-communication technologies ( $\beta=0.355^{***}$ ,  $t=7.261$ ) and processing-actuation technologies ( $\beta=0.202^{**}$ ,  $t=4.372$ ) positively impact the perceived quality improvement of the health care system. Findings also suggested a significant positive impact of perceived quality improvement of the healthcare system ( $\beta=0.313^{***}$ ,  $t=6.980$ ) on healthcare cost reduction. Hence, the study results support hypotheses H1 a and b, H2 a and b, and H3. Moreover, results also supported the H4 a and b (mediation hypothesis), suggesting the underlying mechanism of perceived quality

improvement between the relationship of sensing-communication technologies ( $\beta=0.306^{***}$ ,  $t=6.823$ ) and processing-actuation technologies ( $\beta=0.277^{**}$ ,  $t=5.654$ ) with health care cost reduction.

Additionally, to examine the moderating role of healthcare supply chain management SmartPLS v.4, an interaction term between healthcare supply chain management (HSCM) and perceived quality improvement (PQI), was developed using the product indicator approach.<sup>51</sup> Results revealed that HSCM\*PQI multiplied the direct influence of perceived quality improvement on healthcare cost reduction. At the same time, the  $R^2$  for the main effect of perceived quality improvement on healthcare cost reduction was  $R^2=0.240$ , whereas its  $R^2$  with the interaction effect increased to  $R^2=0.461$ . The  $R^2$  change reflects that the interactive effect of

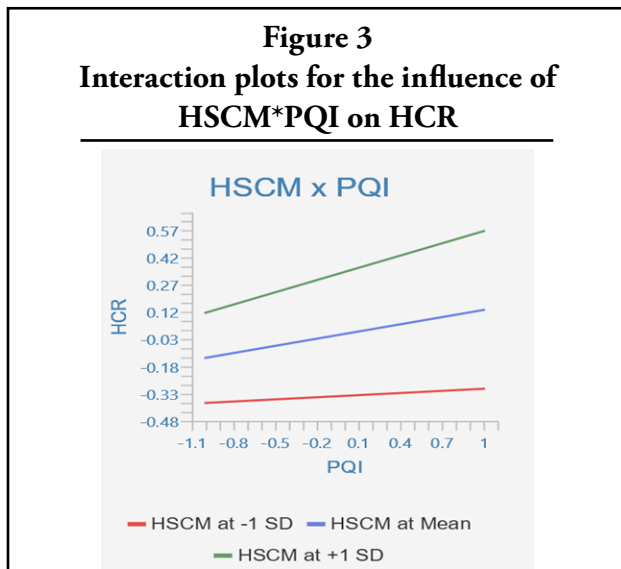
HSCM\*PQI increased healthcare cost reduction' explanatory power by 22.1%. Moreover, plotted

moderation graphs present the interactive effect in Figure 3.

**Table 3**  
**Hypothesis Testing Results**

	Hypotheses	Std. Beta	t-Value	p-values	Supported
<b>H1</b>	a SCT→HCR	0.386	7.751	0.000	Yes
	b PAT→HCR	0.299	6.786	0.000	Yes
<b>H2</b>	a SCT→PQI	0.355	7.261	0.000	Yes
	b PAT→PQI	0.202	4.372	0.000	Yes
<b>H3</b>	PQI→HCR	0.313	6.980	0.000	Yes
<b>H4</b>	a SCT→PQI→HCR	0.306	6.823	0.000	Yes
	b PAT→PQI→HCR	0.277	5.654	0.000	Yes
<b>H5</b>	HSCM*PQI→HCR	0.194	3.920	0.000	Yes

SCT=Sensing-Communication Technologies; PAT=Processing-Actuation Technologies; PQI=Perceived Quality Improvement; HCR=Reduced Healthcare Cost; HSCM=Healthcare Supply Chain Management



The interaction plot in Figure 3 shows a steeper gradient for the highly managed healthcare supply chain than less managed healthcare supply on the relationship of perceived improved quality with healthcare cost reduction. This further shows that when the healthcare system's improved quality interacts with a properly managed supply chain, healthcare costs are reduced. This further presents the significance of managing the supply chain by healthcare institutions to reduce healthcare costs with desired outcomes.

## DISCUSSION AND CONCLUSION

### Key Findings

The current study examined the direct and indirect impact of industry 4.0 technologies, i.e., sensing communication technologies and processing actuation technologies, on reduced health cost via

an underlying mechanism of quality improvement. This investigation took place in the backdrop of the critical nature of the health care system based on limited resources and no living standards in developing nations, Moreover, anticipating the value of healthcare supply chain management, its contingent impact in enhancing the positive influence of sensing communication technologies and processing actuation technologies in achieving economies of scale and cost reduction in the healthcare system has been assessed.

Results revealed a significant impact of sensing communication technologies on improved healthcare quality and reduced healthcare costs. These results further depict that when healthcare institutions adopt modern industry technologies in providing healthcare facilities to patients, their quality of services is improved. It further reflects that since the technologies facilitate the smooth functioning of the system and provide ease of access to healthcare services,<sup>13</sup> the overall cost of healthcare services is reduced. Moreover, since the technologies help healthcare institutions to generate laboratory data, keep patient records and conduct clinical research at ease,<sup>6</sup> therefore, they are in a better position to conduct their services. These results can further be related to the previous studies which postulated the significance of digital technologies intrusion into the healthcare system.<sup>5</sup> Simultaneously previous researchers also asserted the importance of adopting modern technologies in achieving cost-effectiveness.<sup>23,52</sup>

Additionally, results revealed interesting insights regarding the differential influence of both types of technologies on the reduced healthcare system.

Although both technologies had a significant and positive impact on healthcare reduction, however, the results indicated the stronger impact of sensing communication technologies on quality improvement as well as cost reduction of the healthcare system as compared to processing actuation technologies. This strength of the impact size might be because of the greater persuasiveness of sensing communication technologies based on their higher mean of adoption compared to processing actuation technologies.<sup>1</sup> This might also be because of the fact that healthcare institutions in emerging economies are more familiar with sensing communication technologies based on their extensive adoption and cost-reduction benefits.<sup>32</sup> However, the significance of processing actuation technologies cannot be ignored as their significant impact on quality improvement, and cost reduction reflects its continuous advancement in the healthcare sector.

In addition to these direct influences, the results also showed that sensing communication technologies and processing actuation technologies indirectly influence healthcare cost reduction via an underlying mechanism of improved system quality. These results further suggest that sensing communication technologies like cloud computing Internet of Things, and big data depict the fundamental basis for the digital transformation of the healthcare sector.<sup>34</sup> Hence, establishing a technology-facilitated infrastructure allows the integration of processing actuation technologies in the healthcare sector to make it more productive, service-oriented, and smoothly functioning. Researchers have also reported the significance of sensing communication technologies in enhancing organizational learning and productivity.<sup>53</sup> Simultaneously, sensing communication technologies and processing actuation technologies are linked with improved quality. At the same time, the current study proves the significant influence of this improved quality in enhancing cost reduction in the healthcare system.

Furthermore, the current study adds to the existing healthcare literature by presenting the significant contingent impact of a properly managed healthcare supply chain system in enhancing the impact of improved quality on healthcare cost reduction. These results can indirectly be linked with the previous research in terms of presenting the significance of adherence and acceptance of revised practices in terms of quality improvement.<sup>38</sup> Likewise, in delivering patient-centered care, the effectiveness of the revised

system in terms of quality reflects the improvement of the whole system for which the patient experience and satisfaction with the treatment are assessed. Hence when the patients are happy and satisfied with the treatment, the processing, and access to medical care, the quality of that system is considered to be improved.<sup>37</sup> This quality further reduces the cost based on smooth functioning and ease of access to healthcare facilities.

### Theoretical Contribution

Theoretically establishing the general system theory, the current study contributes to the existing healthcare literature in presenting empirical evidence of the significant influence of sensing communication technologies and processing actuation technologies on achieving cost-effectiveness. Previously researchers have considered the influence of digital technologies in the industry 4.0 era on healthcare cost reduction.<sup>1,32</sup> In contrast, the current study has bifurcated the existing technologies in sensing communication and processing actuation to reflect their differential impact on cost reduction and the healthcare sector. In addition to this direct impact, the current study also found an indirect impact via analyzing the influence of enhanced quality to act as a bridge between technology adoption and cost reduction in the healthcare sector. Quality improvement is an important predictor of productivity and enhanced processing in an organization.<sup>54</sup> Therefore, it was of utmost significance to present the theoretical evidence of its underlying mechanism to transmit the significance of technology adoption in the healthcare sector cost reduction. The current study is therefore also a valuable addition to the healthcare system by presenting the critical role of supply chain management in interaction with improved quality to reduce the healthcare system's cost. Considering the significant moderating role of healthcare supply chain management, future studies can further assess its role in integration with digital technologies to enhance patient care services to the masses with low income and limited resources.

### Practical Implications

The current study also has several practical implications for policymakers, healthcare representatives, professionals, and paramedical staff. First, the healthcare institution should focus on adopting technologies in all departments to make the system and procedure smooth and efficient. For that



purpose, they should also organize training programs to educate their professionals and paramedical staff to utilize modern technologies while treating their patients. They should also facilitate the record-keeping, digitalization of appointment procedures, promotion of the mHealth app, etc., to encourage the patients to use the medical facilities regardless of visiting the medical centers. Moreover, sensing communication technologies in the form of cloud computing, big data, and the Internet of Things can be used at a larger scale to automate most of the functions in the healthcare center to smoothen the overall patient experience and visits to the hospitals. Simultaneously, healthcare institutions and administrative departments should enrich their communication and relationships with the stakeholders involved in the supply chain system to make the whole system more economical and affordable, which can further reduce healthcare costs. It is also recommended that health policymakers intensify, design, and modify health educational programs where people should be guided regarding the digital technologies available to extract their benefits regarding healthcare services.

#### **Limitations and the Future Research Directions**

The current study also has some limitations in addition to several strengths, which need to be addressed by future researchers to extract the benefit of the study findings. First, the current study has considered the influence of sensing communication technologies and processing actuation technologies on the cost reduction and quality improvement of the healthcare sector based on the perceptions of the middle and senior managers in the healthcare sector. In contrast, future researchers can also collect data from the patients to analyze their satisfaction and well-being linked with the healthcare sector based on the application of modern technologies in the industry 4.0 era. The current study also considered improved quality's mediatory role in transmitting the significance of sensing communication technologies and processing actuation technologies on healthcare cost reduction. In contrast, future researchers can consider the mediating role of other factors, including the facilitation environment and institutions' culture, to bring valuable insights reading underlying mechanisms for transmitting technology benefits to healthcare cost reduction. The current study has also assessed the moderating role of supply chain management. In contrast, future researchers can consider the number

of trained staff and the attitude and behaviors of the paramedical and non-paramedical staff in the hospitals to examine their contingent role in quality improvement and cost reduction in the healthcare sector. Finally, the current study has been established on a cross-sectional research methodology. Data has been collected from a single source based on a self-reported survey in a one-time horizon. In contrast, future researchers can consider the mixed method approach to finding out other important factors along with digital technologies to achieve economies of scale and cost-effectiveness in the healthcare sector.

#### **HUMAN SUBJECTS STATEMENT**

The current study involves no human subjects for the current study.

#### **CONFLICT OF INTEREST STATEMENT**

The author reports no conflict of interest with anyone.

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