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Live Healthcare Console: Evaluating digital health design models, a South African perspective

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Background: The Department of Health has implemented eHealth systems, yet Gauteng (South Africa) continues to experience healthcare burdens such as prioritising scarce resources. The healthcare technology landscape continues to grow in complexity, yet the availability of real-time information for decision making is limited. A Live Healthcare Console has been proposed to keep key stakeholders informed using real-time information by connecting existing healthcare resources.

Objectives: The objective of the research was to identify and evaluate five eHealth design models to determine whether they can be used to design a Live Healthcare Console. The evaluation of the models considered the Batho Pele Principles, which was created by the South African government to promote service delivery.

Method: A literature review was conducted to identify relevant eHealth models. The models were evaluated and scored using a custom evaluation framework. The models were also scored against the eHealth model aims (combine, communicate, collaborate and connect) identified in this research.

Results: The average score of the five models was 70%, with none fully satisfying the unique South African contexts such as the Batho Pele Principles.

Conclusion: A new design model needs to be created as the foundation for the Live Healthcare Console, as no model which caters to the South African context exists.

Contribution: A custom evaluation framework for eHealth models considering the unique South African contexts was created. Five models were also evaluated and scored against the new framework.

Keywords: eHealth systems; digital healthcare; eHealth models; evaluation criteria; custom evaluation framework; Batho Pele Principles; data information knowledge wisdom pyramid; Live Healthcare Console.

Introduction

The purpose of this research is to determine whether existing eHealth design models from developed and developing countries can be implemented in Gauteng, South Africa, with consideration to local contexts. This is important because the South African healthcare system is constrained by epidemics such as diseases (human immunodeficiency virus [HIV] and tuberculosis), illnesses (chronic and mental health), physical trauma (arising from injury and violence), and mother and child health (maternal, neonatal and child mortality) (Achoki et al. 2022). Furthermore, the healthcare system is burdened by a high rate of orthopaedic cases arising from gunshot wounds (Martin et al. 2017). The Life Esidimeni tragedy of 2016, during which approximately 100 mentally ill patients died (Singh 2017), demonstrated how limited resources, detached information systems and processes as well as uninformed stakeholders, such as healthcare professionals and family members, can have unwanted consequences.

Remenyi and Singh (2015) argue that countries are leveraging technology to improve their e-Government offerings which could have a positive impact on the lives of individuals. These e-Government offerings could include healthcare. Electronic health or 'eHealth' has been utilised to assist in alleviating some of these healthcare challenges from an information and process perspective. eHealth has also become associated with patient level health information and is a key focus area of the Department of Health (Department of Health 2020; Moonsamy & Singh 2019).

eHealth is also showing a significant uptake in patient care (Laflamme et al. 2021). In Gauteng, South Africa, Health Information Systems together with District Health Information Systems have been implemented (Gauteng Province Health 2017; news24 2023). One such necessary initiative is the National Indicator Data Set, which includes indicators such as inpatient management (Day & Gray 2017).

Despite the implementation of many eHealth initiatives such as the National Indictor Data Set, Gauteng's new Health Information System and many other District Health Information Systems, Gauteng continues to be burdened by healthcare challenges. Additionally, eHealth initiatives do not always have the desired outcomes. The National Indicator Data Set for instance is based on historical data and is available monthly, not in real time. The historical rather than the real-time availability of the data could be a result of the disjointed nature of information systems that are implemented in developing countries (Nguyen 2023), which includes South Africa. Gauteng's new Health Information System consequently adds another eHealth system to an already complex technology landscape.

The proliferation of eHealth represents a positive move towards an optimised healthcare system. This research seeks to build on existing systems and ideas to contribute towards a smarter eHealth system landscape. Accordingly, this implies leveraging Gauteng's existing eHealth resources such as systems, stakeholders and information because they cannot function in isolation. It is proposed that existing information such as hospital occupancy be made available to the right people at the right time. This being key stakeholders in real time. A Live Healthcare Console can achieve this by connecting the relevant systems in a way that also supports the key stakeholders (healthcare professionals, managers, patients and citizens). To illustrate the concept of a Live Healthcare Console, four example views have been designed and presented in Appendix 1.

Prior to creating such a system, it must first be designed. A design model was selected for this research as models can be used to describe a problem and to suggest new ideas by describing the necessary components and stripping away those that are unnecessary (Olivier 2004). A literature review was first conducted to identify, evaluate and discuss existing digital healthcare design models (also referred to as eHealth models).

The eHealth models were evaluated within the South African context and local principles to determine whether they are applicable to the South African public healthcare system. This research did not consider individual patient records but instead took a higher-level view from a district or provincial level. Five eHealth models were identified and evaluated during this research. Using a custom evaluation framework, it was determined that none of the evaluated models are a perfect fit for the unique South African context. The average score for the models was 70%. It was then concluded that a new model based on the South African context should be created as the design foundation for the Live Healthcare Console.

Literature review

Eslami Andargoli et al. (2017) argue that the identification, evaluation and interpretation of the available resources related to a subject are fundamental components of a literature review. The aim of this research was to search for, identify and evaluate eHealth models to determine whether a model that encompasses the South African context exists and can be implemented in Gauteng. This therefore justified the need for a literature review of relevant academic literature.

Elements of a systematic literature review, such as a systematic search strategy (Snyder 2019) and screening of existing literature (Moonsamy 2021), were implemented during this literature review. One of the aims of the literature review was to investigate and evaluate existing eHealth information systems design models. The ScienceDirect database which houses scientific and medical research journals (ScienceDirect 2023) was primarily used for the search of relevant material. Over 100 search terms related to eHealth and information systems models were used over a period of 6 months. Appendix 2 indicates the search terms which yielded the top 10 number of results. The search terms were categorised as follows:

eHealth: domain specific related to eHealth,

General: general terms related to the topic, and

Information Systems: general information systems-related terms.

A total of 82 articles published from 2000 to 2023 were deemed relevant based on their abstracts, models, figures and results. These articles were studied, and their insights were incorporated into this research. The literature search results which were related to digital health models were retained. The models from these articles formed the core of the eHealth model evaluation. The evaluation criteria are explained later. Prior to evaluating the eHealth models, principles to guide the development of a Live Healthcare Console were considered. These are discussed in the next section.

Guiding principles towards developing a Live Healthcare Console

Carr, Christ and Ferro (2023) state that the intersection of appropriately implemented technology and human participation within digital health systems results in outcomes which exceed that of isolated human involvement. Tully et al. (2013) argue that the Data-Information-Knowledge-Wisdom pyramid is an appropriate apparatus to use when investigating digital health system components. The Data-Information-Knowledge-Wisdom pyramid has been rearranged as a sequence in Figure 1 to illustrate the steps that can lead from data to wisdom.

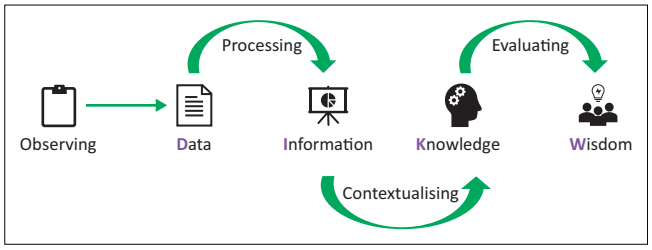
There are three steps highlighted in Figure 1: processing, contextualising and evaluating. These steps can be understood as follows.

Processing: occupancy data are combined with the healthcare department information,

Contextualising: grouping data by region or province to discover patterns, and

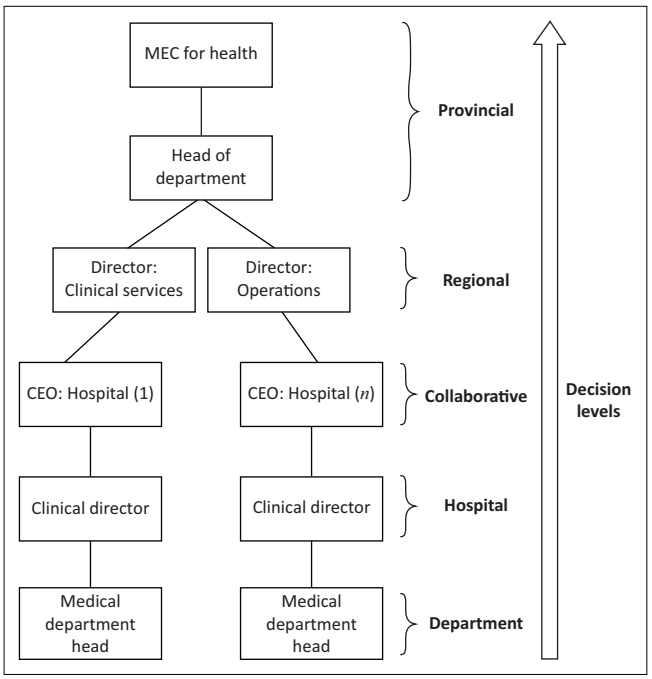
Evaluating: using the contextualised information to inform decision making.

The level of risk in making decisions reduces, as data shifts to wisdom (Hussain et al. 2021). Minimising risk and uncertainty within the healthcare ecosystem can therefore lead to better decisions at the appropriate levels. Figure 2 is an illustration of the clinical and operational organisational structure of the healthcare ecosystem in Gauteng. The organisational structure also depicts decision making at various levels which can be supported with live hospital occupancy information.



Source: Adapted from Tully, M.P., Kettis, Å., Höglund, A.T., Mörlin, C., Schwan, Å. & Ljungberg, C., 2013, 'Transfer of data or re-creation of knowledge – Experiences of a shared electronic patient medical records system', *Research in Social and Administrative Pharmacy* 9(6), 965–974. https://doi.org/10.1016/j.sapharm.2013.02.004

FIGURE 1: Steps needed to move from eHealth data to wisdom.



Source: Adapted from Department of Health, 2021, *Department of health annual report*, viewed n.d., from https://provincialgovernment.co.za/department_annual/997/2021-gauteng-health-annual-report.pdf

MEC, Member of the Executive Council.

FIGURE 2: Organisational structure of the Gauteng healthcare ecosystem.

The Batho Pele Principles initiated in 1997 (Luthuli & Kalusopa 2018) were created by the South African Government to promote service delivery (Joel 2022), which includes healthcare services (Khoza & Du Toit 2011). The Batho Pele Principles are evolving and currently include nine principles (sometimes referred to as guidelines) which are described in Appendix 3. These principles can be supported by the Data-Information-Knowledge-Wisdom pyramid allowing for informed decisions from the point of patient care to strategic levels.

The Batho Pele Principles described in Appendix 3 were incorporated into the evaluation criteria of the existing eHealth models. During this research, models that describe solutions or ideas related to eHealth graphically were investigated to determine their merits and limitations. The models were visually inspected and evaluated using the evaluation criteria described in the next section.

Research methodology

The literature review identified five appropriate eHealth models to be evaluated and discussed. These five models were evaluated using two evaluation methods. Odhiambo-Otieno (2005) identified a set of evaluation criteria for the three phases of information systems' implementation for the District Health Management Information Systems of Kenya. These phases are pre-implementation, concurrent and post-operational. As this research focuses on a design model, only the first phase (pre-implementation) was considered. These criteria are described in Appendix 4.

The 'human, organization and technology-fit factors' commonly known as HOT-fit is a framework aimed at Health Information System evaluation (Yusof et al. 2008). The three themes and six dimensions that form part of this framework are explained in Appendix 5 and utilised in Table 1a and Table 1b.

The four main aims of an eHealth model were conceptualised with the intention of them contributing to the critical success factors of a digital health system. The eHealth model aims are *combine, communicate, collaborate and connect*. These critical success factors can include customer (which can include patients) acceptance, interoperability and stakeholder collaboration (Kumar et al. 2023). It must be noted that though interoperability has been identified, integration can also be considered in cases where there are heterogeneous systems. The four main eHealth model aims are described in Appendix 6.

Forming a relationship between the real-time hospital capacities across the various hospitals in Gauteng requires the aims described earlier to be considered when establishing a set of evaluation criteria. The themes, dimensions and investigated evaluation criteria were then combined into the final evaluation criteria. These criteria and their relationship with the Batho Pele Principles are defined in Appendix 7.

TABLE 1a: Evaluation scoring matrix.

Evaluation criteria	Aims of the model				Total
	Combine	Communicate	Collaborate	Connect	
Adequacy	1	1	1	1	4
Compatibility	1	-	-	1	2
Data handling	1	1	-	1	3
Effectiveness	-	-	1	-	1
Environment	-	-	-	1	1
Information quality	1	1	-	1	3
Information systems standards	-	-	1	-	1
Security	1	-	1	1	3
Service quality	-	-	1	-	1
Structure	-	-	1	-	1
System quality	1	1	1	-	3
System use	-	-	1	-	1
User satisfaction	-	-	1	-	1
Total	**6**	**4**	**9**	**6**	**25**

TABLE 1b: Evaluation scoring matrix.

Principle name	Batho Pele Principle				Total
	Combine	Communicate	Collaborate	Connect	
Best value	1	1	1	1	4
Information	3	1	2	2	8
Courtesy	2	1	1	2	6
Openness and transparency	1	1	-	1	3
Service standards	1	1	4	1	7
Customer impact	-	-	1	1	2
Access	-	-	1	-	1
Redress	-	-	1	-	1
Consultation	-	-	1	-	1
Total	**8**	**5**	**12**	**8**	**33**

Results

Each of the five eHealth models selected was scored based on the evaluation criteria which gave a score out of 25. The scores were then grouped according to the eHealth model aims. They were scored as follows: combine (score out of 6), communicate (score out of 4), collaborate (score out of 9) and connect (score out of 6).

The aims and evaluation criteria were then matched. They were assigned a score of 1 if the model catered for the evaluation criterion and 0 if it did not. The Batho Pele Principles were grouped by the evaluation criteria and were scored out of 33 based on the scoring matrix presented in Table 1a and Table 1b. Weighted scoring was not applied to the criteria as an equal weighting was assumed. Scoring was applied only for the relevant aims.

Five existing eHealth models were selected from the 82 relevant articles to be investigated in this research. Their selection was due to their relevance to certain Batho Pele Principles as well as the four aims of an eHealth model.

Model 1: Holistic eHealth model (*Al-Sharhan, Omran & Lari 2019*)

Model 1 is based on the Kuwait healthcare system and intends to address issues such as healthcare environment complexity, copious amounts of information and the lack of a consolidated eHealth view. In addition to this, the large number of systems, rules, procedures and stakeholders within the eHealth domains poses significant obstacles. The model therefore aims to address as many of these concerns as possible. Model 1's scores are presented as follows:

Evaluation criteria: 76%

Batho Pele Principles: 82%

Aims: 75%

The model illustration and evaluation scores are presented in Appendix 8.

Model 2: The computing ecosystem suitable for modern and future medical applications (*Alekseeva et al. 2022*)

The use of Cloud Computing for the storage and sharing of large amounts of health-related data is illustrated by Model 2, which was influenced by Finland's healthcare system. The recent influx of wearable devices, which use cloud-based services, has made a significant contribution to the amount of eHealth data being generated. This is in reference to patient data and not necessarily hospital occupancy data; however, the overall model does contain many aspects that are applicable to this scenario. Model 2's scores are presented as follows:

Evaluation criteria: 40%

Batho Pele Principles: 42%

Aims: 50%

The model illustration and evaluation scores are presented in Appendix 9.

Model 3: Experimental environment setup (*da Silva, Gonçalves & Dantas 2019*)

The main scenario of Model 3, based on the Brazilian perspective, is assisted living for patients that require constant monitoring. Information from wearable and other devices is shared in real time with healthcare services. Due to the increasing number of wearable devices which constantly generate and share information, additional strain can be introduced to a cloud-based system. New technologies such as Software Define Networking and Autonomic Network Management therefore play a role in this model. Model 3's scores are presented as follows:

Evaluation criteria: 76%

Batho Pele Principles: 82%

Aims: 75%

The model illustration and evaluation scores are presented in Appendix 10.

Model 4: Elements of Internet of Things for enabling sustainable smart environments (*Deebak et al. 2022*)

Some of the challenges associated with modern urban cities can be alleviated using smart city services (Kim 2022). Model 4 emphasises improved healthcare with the use of IoT devices. A distributed approach can have advantages to existing cloud-based infrastructure as they can reduce network traffic and intensive data processing needs. Model 4's scores are presented as follows:

Evaluation criteria: 76%

Batho Pele Principles: 82%

Aims: 75%

The model illustration and evaluation scores are presented in Appendix 11.

Model 5: Design of smart ambulance system (*Dumka & Sah 2019*)

Model 5, which contains influences from the Indian healthcare system, illustrates that, when coupled with remote mobile health systems, eHealth services can be enhanced. During an emergency, real-time patient data (raw data) from the incoming ambulance can be shared with the doctors and other healthcare professionals who are waiting for the patient to arrive. This information could improve the doctors' ability to assist the patient. Model 5's scores are presented as follows:

Evaluation criteria: 76%

Batho Pele Principles: 82%

Aims: 75%

The model illustration and evaluation scores are presented in Appendix 12.

Models 1, 3, 4 and 5 shared the same overall scores. Model 2, however, scored lower overall. This is due to its lack of representing a consolidated repository and not adequately representing the relevant stakeholders. The scores of all five models were simplified and averaged based on the eHealth model aims and expressed as a percentage. If an aim was catered to in a model, then a score of 1 was assigned; if not, no score was assigned. The summary of the scores is represented in Table 2.

The average score for the five models was 70%. This is illustrated in Figure 3.

Discussion

The five investigated models were evaluated against the aims of an eHealth model which were underpinned by the Batho Pele Principles specific to South Africa. The investigated models, with roots in Brazil, Finland, India and Kuwait, were created with their own distinctive perspectives. Specific contexts can influence analyses (Davison & Martinsons 2016). This could explain why none of the models scored 100% for all the eHealth model aims. For the South African context, a model that encompasses local factors would therefore be more appropriate. This model, however, should also embody elements of generalisability (Cheng, Dimoka & Pavlou 2016) for it to be valuable in similar settings such as other African and developing countries.

The Life Esidimeni tragedy has demonstrated the need for better information, which can influence better decisions, resulting in more desirable outcomes. When targeting these benefits, digital health models should therefore promote more than just 'Big Data' collection. The data should eventually lead to wisdom which can inform future healthcare objectives. A model to support the four eHealth aims identified in this research, which addresses the South African context, does not yet exist.

To design an appropriate eHealth model for Gauteng, South Africa, further research is needed. For the next phase of the research, appropriate stakeholders will be interviewed using

TABLE 2: Summary of model scores based on the four eHealth model aims.

Model	Combine	Communicate	Collaborate	Connect
Model 1	-	1	1	1
Model 2	-	1	-	1
Model 3	-	1	1	1
Model 4	1	1	1	-
Model 5	1	1	1	-

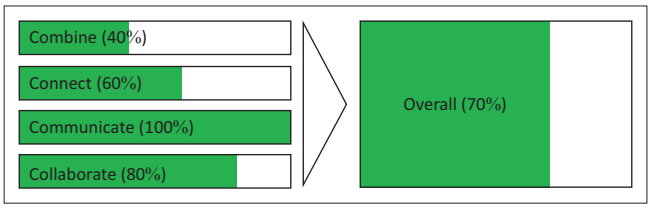


FIGURE 3: The combined evaluation results for all five models.

a semi-structured approach. Their insights will be used to establish how to construct a contextually relevant digital health model for Gauteng.

Conclusion

From the 82 pertinent articles, 5 played a pivotal role in this research as they contributed to the five eHealth models which were evaluated. The overall score of 70% showed that most of the eHealth model aims were covered by the models, but no single model catered to all the eHealth model aims or to the Batho Pele Principles. Though these models did not individually cater to all the aims, together they provided valuable insights which will be incorporated into future research. This study was limited by the number of evaluated models.

Healthcare information and the supporting systems exist, yet this does not always support positive outcomes. In the Life Esidimeni Section 27 report, it was stated that during the interfacility transfers, patient records were lost and in some cases the whereabouts of the patients themselves were not known (Section 27, 2023). Some facets of the healthcare system such as real-time hospital occupancy information therefore need to be suitably designed. To accomplish the four eHealth model aims identified in this research, which targets the uniting and disseminating of real-time eHealth data, a new model incorporating the merits of the five investigated models as well as emerging technologies would need to be created. This is the motivation for the forthcoming research.

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Competing interests

The authors have declared that no competing interest exists.

Authors' contributions

W.M. is the main author of the article. He co-conceptualised the article, created the evaluation criteria and wrote most of the article. S.S. is my research supervisor. He co-conceptualised the article, provided inputs into the structure, evaluation and methods. He also assisted with writing and reviewing.

Ethical considerations

Ethical clearance for this research was obtained from the College of Agriculture & Environmental Sciences Health Research Ethics Committee (Ref No.: 2023/CAES_HREC/585).

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Data availability

Relevant tables and figures with data have been included in the appendix of the document.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

References

Achoki, T., Sartorius, B., Watkins, D., Glenn, S.D., Kengne, A.P., Oni, T. et al., 2022, 'Health trends, inequalities and opportunities in South Africa's provinces, 1990–2019: Findings from the Global Burden of Disease 2019 Study', *Journal of Epidemiology and Community Health* 76(5), 471–481. https://doi.org/10.1136/jech-2021-217480

Alekseeva, D., Ometov, A., Arponen, O. & Lohan, E.S., 2022, 'The future of computing paradigms for medical and emergency applications', *Computer Science Review* 45, 100494. https://doi.org/10.1016/j.cosrev.2022.100494

Al-Sharhan, S., Omran, E. & Lari, K., 2019, 'An integrated holistic model for an eHealth system: A national implementation approach and a new cloud-based security model', *International Journal of Information Management* 47, 121–130. https://doi.org/10.1016/j.ijinfomgt.2018.12.009

Bester, G., 2009. *SANRAL Freeway Management System (FMS)*, Johannesburg, https://www.itssa.org/wp-content/uploads/files/events/2009/e_transport/presentations/sitevisit/Gail_Bester_SANRAL_FMS.pdf.

Carr, L.H., Christ, L. & Ferro, D.F., 2023, 'The electronic health record as a quality improvement tool', *Clinics in Perinatology* 50(2), 473–488. https://doi.org/10.1016/j.clp.2023.01.008

Cheng, Z. (Aaron), Dimoka, A. & Pavlou, P.A., 2016, 'Context may be King, but generalizability is the Emperor!', *Journal of Information Technology* 31(3), 257–264. https://doi.org/10.1057/s41265-016-0005-7

Da Silva, M.P., Gonçalves, A.L. & Dantas, M.A.R., 2019, 'A conceptual model for quality of experience management to provide context-aware eHealth services', *Future Generation Computer Systems* 101, 1041–1061. https://doi.org/10.1016/j.future.2019.07.033

Davison, R.M. & Martinsons, M.G., 2016, 'Context is king! Considering particularism in research design and reporting', *Journal of Information Technology* 31(3), 241–249. https://doi.org/10.1057/jit.2015.19

Day, C. & Gray, A., 2017, *Health and related indicators*, Health Systems Trust.

Deebak, B.D., Memon, F.H., Cheng, X., Dev, K., Hu, J., Khowaja, S.A. et al., 2022, 'Seamless privacy-preservation and authentication framework for IoT-enabled smart eHealth systems', *Sustainable Cities and Society* 80, 103661. https://doi.org/10.1016/j.scs.2021.103661

Department of Health, 2021, *Department of health annual report*, viewed n.d., from https://provincialgovernment.co.za/department_annual/997/2021-gauteng-health-annual-report.pdf.

Department of Health, 2020, *National Digital Health Strategy for South Africa 2019 – 2024*.

Department of Social Development, 2022, *Batho Pele*, viewed 07 June 2022, from https://www.dsd.gov.za/index.php/about/batho-pele.

Dumka, A. & Sah, A., 2019, 'Smart ambulance system using concept of big data and internet of things', in N. Dey, A.S. Ashour, C. Bhatt, S.J. Fong, (eds.), *Healthcare Data Analytics and Management*, Academic Press, June 12–13, 2017, pp. 155–176. https://doi.org/10.1016/B978-0-12-815368-0.00006-3

Eslami Andargoli, A., Scheepers, H., Rajendran, D. & Sohal, A., 2017, 'Health information systems evaluation frameworks: A systematic review', *International Journal of Medical Informatics* 97, 195–209. https://doi.org/10.1016/j.ijmedinf.2016.10.008

Gauteng Province Health, 2017, *Gauteng department of health annual report 2016 / 2017*, viewed n.d., from https://www.gauteng.gov.za/media/AnnualReports/GautengDepartmentofHealthAnnualReport2016-17.pdf.

Hosseini Teshnizi, S., Hayavi Haghighi, M.H. & Alipour, J., 2021, 'Evaluation of health information systems with ISO 9241-10 standard: A systematic review and meta-analysis', *Informatics in Medicine Unlocked* 25, 100639. https://doi.org/10.1016/j.imu.2021.100639

Hussain, M., Satti, F.A., Ali, S.I., Hussain, J., Ali, T., Kim, H.-S. et al., 2021, 'Intelligent knowledge consolidation: From data to wisdom', *Knowledge-Based Systems* 234, 107578. https://doi.org/10.1016/j.knosys.2021.107578

ISO, 2020, *ISO 9241-110:2020(en) Ergonomics of human-system interaction – Part 110: Interaction principles*, viewed 11 April 2022, from https://www.iso.org/obp/ui/#iso:std:iso:9241:-110:ed-2:v1:en.

Joel, C., 2022, 'Batho Pele principles in the 21st Century: The case of the Department of Home Affairs, South Africa', *African Journal of Development Studies (formerly AFFRIKA Journal of Politics, Economics and Society)* 2022(1), 207–222. https://doi.org/10.31920/2634-3649/2022/SIv2a12

Khoza, V. & Du Toit, H., 2011, 'The Batho Pele Principles in the health services', *Professional Nursing Today* 15, 8–11.

Kim, J., 2022, 'Smart city trends: A focus on 5 countries and 15 companies', *Cities* 123, 103551. https://doi.org/10.1016/j.cities.2021.103551

Kumar, A., Mani, V., Jain, V., Gupta, H. & Venkatesh, V.G., 2023, 'Managing healthcare supply chain through artificial intelligence (AI): A study of critical success factors', *Computers & Industrial Engineering* 175, 108815. https://doi.org/10.1016/j.cie.2022.108815

Laflamme, L., Chipps, J., Barrett, D., Brysiewicz, P., Duys, R., Evans, K. et al., 2021, 'Dos and don'ts for mHealth-based clinical support among clinicians in South Africa: Results from a 1-day workshop', *South African Medical Journal* 111(5), 416–420. https://doi.org/10.7196/SAMJ.2021.v111i5.15400

Luthuli, L.P. & Kalusopa, T., 2018, 'The management of medical records in the context of service delivery in the public sector in KwaZulu-Natal, South Africa: The case of Ngwelezana hospital', *South African Journal of Libraries and Information Science* 83(2), 1–11. https://doi.org/10.7553/83-2-1679

Martin, C., Thiart, G., McCollum, G., Roche, S. & Maqungo, S., 2017, 'The burden of gunshot injuries on orthopaedic healthcare resources in south Africa', *South African Medical Journal* 107, 626–630. https://doi.org/10.7196/SAMJ.2017.v107i7.12257

Moonsamy, W., 2021, *An investigation into digital vaccination records for minors in Gauteng, South Africa*, University of South Africa.

Moonsamy, W. & Singh, S., 2019, 'An investigation into electronic vaccination cards for minors in Gauteng, South Africa', in *IEEE International Multidisciplinary Information Technology and Engineering Conference (IMITEC) 2019*, IEEE, November 21–22, 2019, pp. 452–455.

news24, 2023, *How Gauteng's new information system will improve the quality of healthcare accreditation Yoliswa Sobuwa Comments Comments add bookmark*, viewed 24 August 2023, from https://www.news24.com/news24/southafrica/news/how-gautengs-new-information-system-will-improve-the-quality-of-healthcare-20230822.

Nguyen, T.N., 2023, 'Developing health information systems in developing countries: Lessons learnt from a longitudinal action research study in Vietnam', *Electronic Journal of Information Systems in Developing Countries* 89(5)1–27. https://doi.org/10.1002/isd2.12268

Odhiambo-Otieno, G.W., 2005, 'Evaluation criteria for district health management information systems: Lessons from the Ministry of Health, Kenya', *International Journal of Medical Informatics* 74(1), 31–38. https://doi.org/10.1016/j.ijmedinf.2004.09.003

Olivier, M.S., 2004, *Information technology research*, 2nd edn., Van Schaik Publishers, Pretoria.

Remenyi, D. & Singh, S., 2015, 'Is there a paradox involved with the progress represented by ICT developments?', *Electronic Journal of IS Evaluation* 18, 77–92.

ScienceDirect, 2023, *ScienceDirect*, viewed 02 February 2023, from https://www.sciencedirect.com.

Section 27, 2023, *Life Esidimeni*, viewed 26 May 2023, from https://section27.org.za/campaigns/life-esidimeni/#ombud.

Singh, S., 2017, 'Developing IT systems in a d-Government Era: Contemporary South Africa', in V. Borges, V & J.C.D. Rouco (eds.), *17th European Conference on Digital Government*, Lisbon, June 12–13, 2017, pp. 188–196.

Snyder, H., 2019, 'Literature review as a research methodology: An overview and guidelines', *Journal of Business Research* 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Tully, M.P., Kettis, Å., Höglund, A.T., Mörlin, C., Schwan, Å. & Ljungberg, C., 2013, 'Transfer of data or re-creation of knowledge – Experiences of a shared electronic patient medical records system', *Research in Social and Administrative Pharmacy* 9(6), 965–974. https://doi.org/10.1016/j.sapharm.2013.02.004

Yusof, M.M., Kuljis, J., Papazafeiropoulou, A. & Stergioulas, L.K., 2008, 'An evaluation framework for health information systems: Human, organization and technology-fit factors (HOT-fit)', *International Journal of Medical Informatics* 77(6), 386–398. https://doi.org/10.1016/j.ijmedinf.2007.08.011

Appendices starts on the next page →

Appendix sections

Appendix 1

TABLE 1-A1: Example views of a Live Healthcare Console.

Example view	Description
Live Healthcare console: Hospital Manager **Hospital name:** Chris Hani Baragwanath Hospital **Date:** 01 January 2024 **Region:** City of Joburg **Overall occupancy** 58% **Bed occupancy** **Cardiology:** 60% (12/20) **Renal:** 90% (18/20) **Respiratory:** 30% (4/12) **Emergency department** **Occupied:** 50% (10/20) **Discharging: 2** **Incoming: 5**	The Hospital Manager view shows the overall bed occupancy of each department. The emergency department could include the incoming and discharging patients.
Live Healthcare console: Regional Manager **Region name:** City of Joburg **Date:** 01 January 2024 **Province:** Gauteng **Overall occupancy** 70% **Hospital bed occupancy (All departments)** **Chris Hani Baragwanath Hospital:** 58% **Charlotte Maxeke Johannesburg Academic Hospital:** 82%	The Regional Manager view shows the higher level of bed occupancy information for hospitals grouped by the current region. A regional manager should have the ability to drill down to a more detailed hospital view.
Live Healthcare console: Provincial Manager **Province name:** Gauteng **Date:** 01 January 2024 **Province:** Gauteng **Overall occupancy** 60% **Hospital bed occupancy by region (All departments)** **City of Joburg:** 60% **City of Tshwane:** 80% **Ekurhuleni:** 40% **Sedibeng:** 40% **West Rand:** 80%	The Provincial Manager view shows a higher level of bed occupancy information for the regions grouped by the province. A provincial manager should have the ability to go to a more detailed regional and hospital view.
Live Healthcare console: Provincial Manager **Province name:** Gauteng **Date:** 01 January 2024 **Broadcast method:** Freeway management system **Closest hospital emergency department occupancy** 70% **Existing freeway management system infrastructure**  **Tambo Memorial Hospital** Tambo memorial hospital Emergency department: 60% full Travel time: 12 min	Incoming patients or citizens could have information that is broadcasted to them via existing or new platforms. The major highways in Gauteng utilise a Freeway Management System (FMS) which is a network of digital signboards which displays real-time information (Bester 2009). This could be extended to include the bed occupancy of the nearby hospitals.

Appendix 2

TABLE 1-A2: Top 10 search terms.

Search term	Category	Number of results
Information systems modelling	Information systems	3 797 372
Information systems standards	Information systems	3 232 230
Constructing a model	General	2 353 219
Transport system	General	2 225 286
Constructing a research model	General	1 755 101
Health and technology	eHealth	1 377 879
Constructing an information systems model	Information systems	1 245 673
How to construct an information systems model	Information systems	1 245 673
Model scoring technique	General	736 378
Healthcare	eHealth	703 583

Appendix 3

TABLE 1-A3: Description of the Batho Pele Principles.

Principle	Description
Consultation	Engaging with customers to determine their needs
Service standards	Offering services that meet customers' expectations
Access	Ensuring that the public has access to services
Courtesy	Treating customers respectfully
Information	Ensuring that information regarding services is readily available
Openness and transparency	Promoting honesty with customers
Redress	Rectifying customer issues
Best value	Effectively utilising resources to ensure maximum customer benefit
Customer impact	Ensuring synergy among all other Batho Pele Principles

Source: Adapted from Department of Social Development, 2022, *Batho Pele*, viewed 07 June 2022, from https://www.dsd.gov.za/index.php/about/batho-pele

Appendix 4

TABLE 1-A4: Evaluation criteria considered.

Evaluation criteria	Description
Policy and objectives	Determines whether the objectives of the new information system have been documented and whether it will promote the supporting of healthcare services. • **Compatibility:** will the new information system be compatible with existing systems? • **Information systems standards:** will the new information system conform to information systems standards. These standards can include ISO 9241–110 (Hosseini Teshnizi, Hayavi Haghighi & Alipour 2021), which refer to usability problems including insufficient, poor and misleading information (ISO 2020). • **Data collection and dissemination including information processing:** will manual and digital information be treated as private and confidential? • **Security:** will information be stored safely?
Technical feasibility	This is related to the infrastructure which comprises of technical components (hardware and software) and human capital. • **Effectiveness:** will the new information system have the intended value? • **Adequacy:** how much of the objectives can be achieved by utilising the available resources?
Financial viability†	What financial investment is required for the new information system and will this investment align with the perceived benefits?
Political viability	Will the implementation of the new information system have the support of the key decision makers?

Source: Adapted from Odhiambo-Otieno, G.W., 2005, 'Evaluation criteria for district health management information systems: Lessons from the Ministry of Health, Kenya', *International Journal of Medical Informatics* 74(1), 31–38. https://doi.org/10.1016/j.ijmedinf.2004.09.003

†, This criterion was excluded as the study did not incorporate any financial aspects.

Appendix 5

TABLE 1-A5: Summary of the themes and dimensions according to the human, organisation and technology-fit framework.

Theme	Dimensions	Considerations
Technology	System quality	Is the system flexible, reliable, accurate and useful?
	Information quality	Is the information accurate, relevant and useful?
	Service quality	Is the system fast and responsive and is there enough technical support?
Human	System use	How often do the users use the system and what functions do they use? Are they trained and happy to use the system or are they reluctant to use it?
	User satisfaction	Do the users enjoy using the system? Is it useful and does it aid them in decision making?
Organisation	Structure	What is the hierarchy, management, structure and communication of the organisation?
	Environment	Is there localisation, competition or interorganisational relationships to consider?

Appendix 6

TABLE 1-A6: Description of the four main aims and the related CSFs.

eHealth model aim	Description	Related CSF(s)
Combine	Represents a consolidated repository of hospital occupancy data.	Interoperability
Communicate	Provides real-time data to the relevant stakeholders.	Customer acceptance, stakeholder collaboration, interoperability
Collaborate	Involves the relevant stakeholders in the design and use of the system.	Stakeholder collaboration, interoperability
Connect	Integrates into internal and external systems.	Interoperability

CSFs, Critical success factors.

Appendix 7

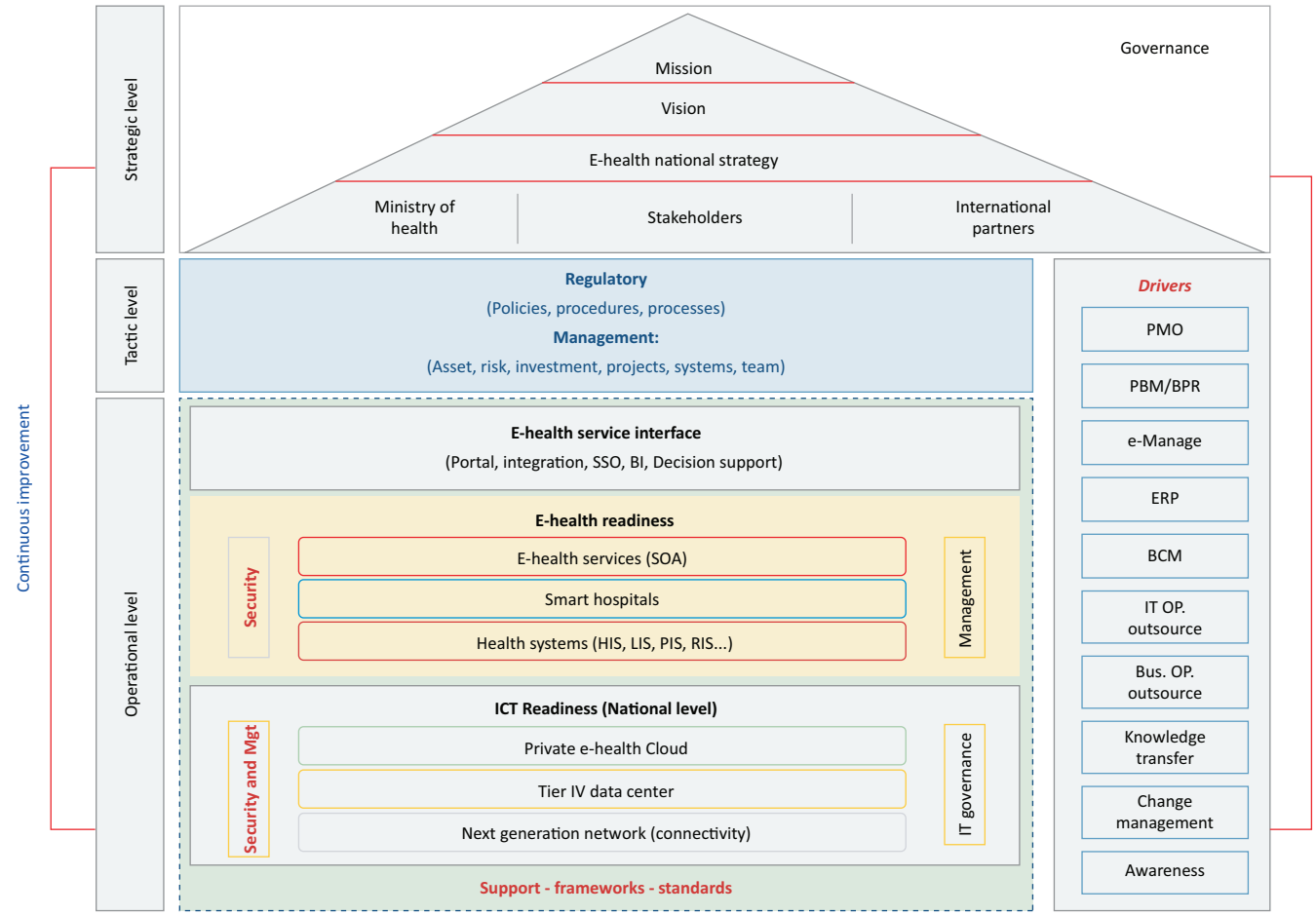
TABLE 1-A7: Definitions of the evaluation criteria used in this research and their relevance to the Batho Pele Principles.

Evaluation criteria	Related Batho Pele Principle	Rationale	Related eHealth model aims
Adequacy	Best value	The effective and optimised use of existing resources.	Combine Communicate Collaborate Connect
Compatibility	Information	Compatibility of systems promotes the availability of accurate information.	Combine Connect
Data handling	Courtesy	Ensuring the safety and privacy of customer information encourages the respectful treatment of customers.	Combine Communicate Connect
	Openness and transparency	Honesty is a key element in treating customer information as private and confidential.	
Effectiveness	Service standards	Systems that meet customer expectations ensure its effectiveness.	Collaborate
Environment	Customer impact	Within an environment, there can be many systems that need to interact. This is made possible if there is synergy among the Batho Pele Principles.	Connect
Information quality	Service standards	The accuracy and usefulness of information is vital to ensuring that the system and information meets the customers' expectations.	Combine Communicate Connect
Information systems standards	Access	Access to services includes that of the associated information. The information itself needs to be accurate and systems must be usable.	Collaborate
	Service standards	Having good information systems standards ensures that customer expectations are met.	
	Redress	Customer issues can be dealt with by utilising effective information systems and business processes which are based on accepted standards.	
Security	Courtesy	Ensuring the safety of customers' information is one of the steps towards treating them respectfully.	Combine Collaborate Connect
	Information	The safe and secure storage of information promotes the availability of information.	
Service quality	Service standards	Systems that are reliable ensure that the customers' expectations are met.	Collaborate
Structure	Consultation	The consultation principle refers to communication with customers, but in this instance, it could refer to communication between key stakeholders within an organisation.	Collaborate
System quality	Information	Systems that are useful and reliable ensure that information is readily available.	Combine Communicate Collaborate
System use	Service standards	Systems that are frequently used by satisfied customers meet customer expectations.	Collaborate
User satisfaction	Customer impact	For customers to be satisfied with a system, all other principles need to collaborate.	Collaborate

Appendix 8

TABLE 1-A8: Model 1 illustration and evaluation scores.

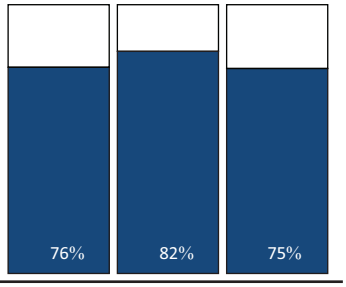
Model illustration



Evaluation

Model 1: Evaluation scores			
Adequacy (3/4)	Compatibility (1/2)	Data handling (2/3)	Effectiveness (1/1)
Environment (1/1)	Information quality (2/3)	Information systems standards (1/1)	Security (2/3)
Service quality (1/1)	Structure (1/1)	System quality (2/3)	System use (1/1)
User satisfaction (1/1)	**Total score: 19/25**		

BPP scores		Model aims	
Access (1/1)	Best value (3/4)	Combine	
Consultation (1/1)	Courtesy (4/6)	Communicate	
Customer impact (2/2)	Information (7/8)	Collaborate	
Openness and transparency (2/3)	Service standards (6/7)	Connect	
Redress (1/1)	**Total score: 27/33**	Represented	Not represented



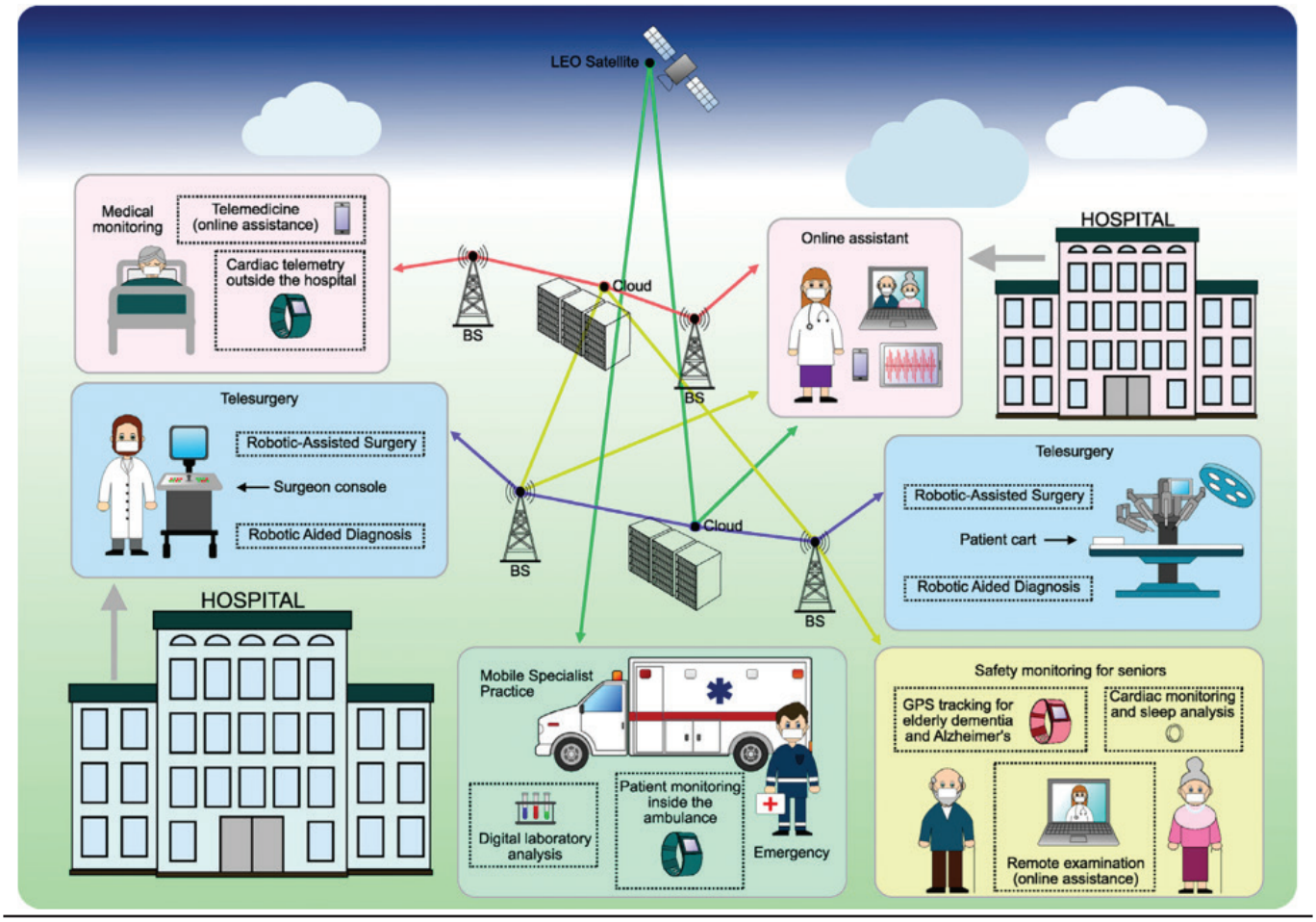
Source: Al-Sharhan, S., Omran, E. & Lari, K., 2019, 'An integrated holistic model for an eHealth system: A national implementation approach and a new cloud-based security model', *International Journal of Information Management* 47, 121–130. https://doi.org/10.1016/j.ijinfomgt.2018.12.009

SSO, Single sign-on; BI, Business Intelligence; PMO, Program Management Office; PBM/BPR, Business Process Engineering/Re-engineering; SOA, Service oriented architecture; ERP, Enterprise resource planning; BCM, Business Continuity Management; IT OP., Information Technology Operations; Bus. OP., Business Operations; HIS, Health Information System; LIS, Lab Information System; RIS, Radiology Information System; BPP, Batho Pele Principles.

Appendix 9

TABLE 1-A9: Model 2 illustration and evaluation scores.

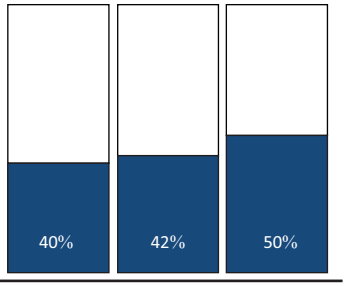
Model illustration



Evaluation

Model 2: Evaluation scores			
Adequacy (2/4)	Compatibility (1/2)	Data handling (2/3)	Effectiveness (1/1)
Environment (1/1)	Information quality (2/3)	Information systems standards (1/1)	Security (2/3)
Service quality (0/1)	Structure (0/1)	System quality (1/3)	System use (0/1)
User satisfaction (0/1)	**Total score: 10/25**		

BPP scores		Model aims	
Access (0/1)	Best value (2/4)	Combine	
Consultation (0/1)	Courtesy (3/6)	Communicate	
Customer impact (1/2)	Information (4/8)	Collaborate	
Openness and transparency (2/3)	Service standards (2/7)	Connect	
Redress (0/1)	**Total score: 14/33**	Represented	Not represented



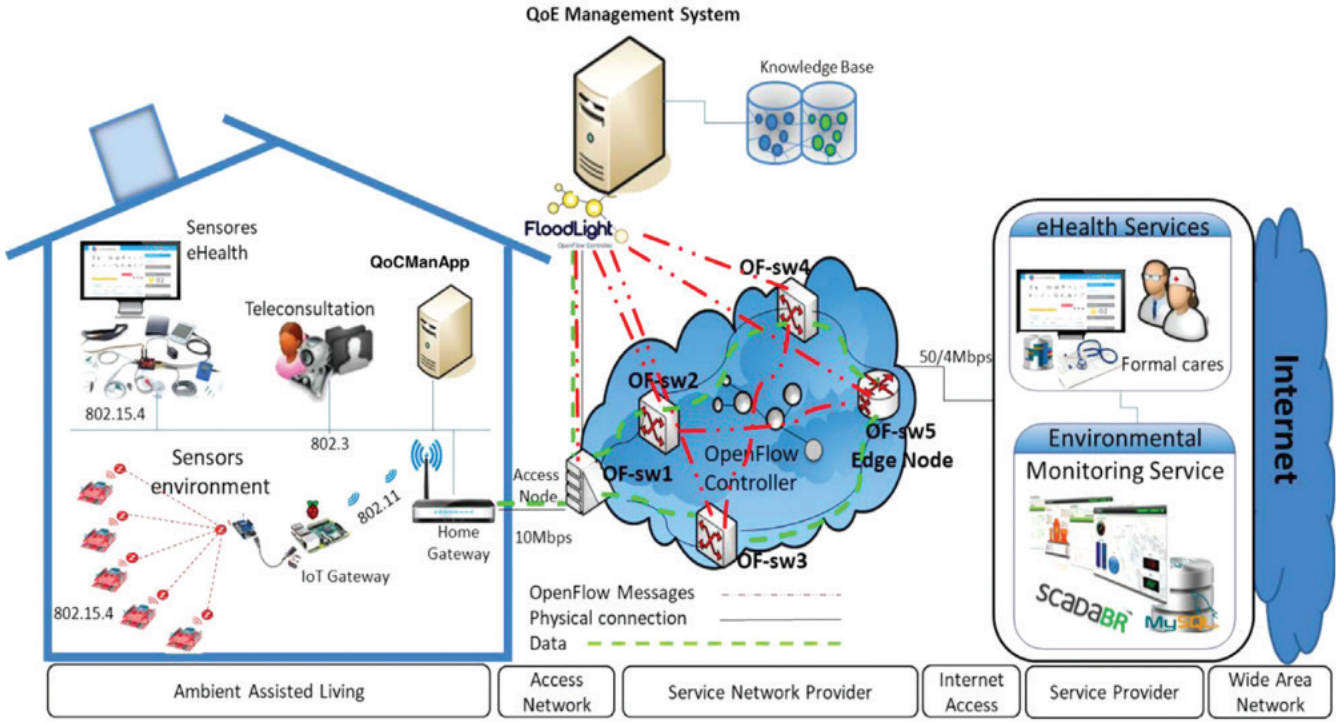
Source: Alekseeva, D., Ometov, A., Arponen, O. & Lohan, E.S., 2022, 'The future of computing paradigms for medical and emergency applications', *Computer Science Review* 45, 100494. https://doi.org/10.1016/j.cosrev.2022.100494

BPP, Batho Pele Principles.

Appendix 10

TABLE 1-A10: Model 3 illustration and evaluation scores.

Model illustration



Evaluation

Model 3: Evaluation scores			
Adequacy (3/4)	Compatibility (1/2)	Data handling (2/3)	Effectiveness (1/1)
Environment (1/1)	Information quality (2/3)	Information systems standards (1/1)	Security (2/3)
Service quality (1/1)	Structure (1/1)	System quality (2/3)	System use (1/1)
User satisfaction (1/1)	**Total score: 19/25**		

BPP scores		Model aims		Evaluation	BPP	Aims
Access (0/1)	Best value (3/4)	Combine				
Consultation (1/1)	Courtesy (4/6)	Communicate				
Customer impact (2/2)	Information (7/8)	Collaborate				
Openness and transparency (2/3)	Service standards (6/7)	Connect				
Redress (1/1)	**Total score: 27/33**	Represented	Not represented	76%	82%	75%

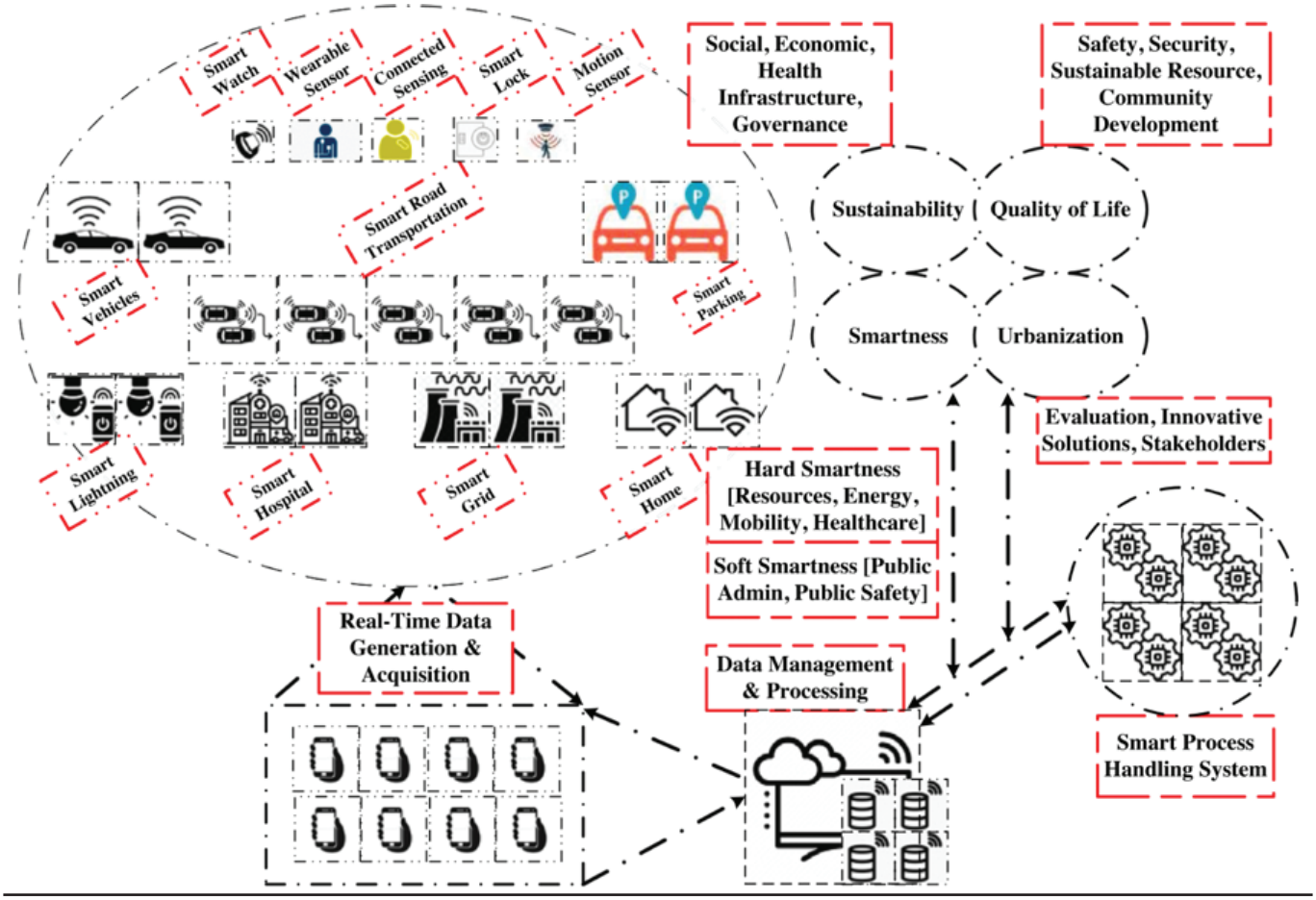
Source: Da Silva, M.P., Gonçalves, A.L. & Dantas, M.A.R., 2019, 'A conceptual model for quality of experience management to provide context-aware eHealth services', *Future Generation Computer Systems* 101, 1041–1061. https://doi.org/10.1016/j.future.2019.07.033

BPP, Batho Pele Principles.

Appendix 11

TABLE 1-A11: Model 4 illustration and evaluation scores.

Model illustration



Evaluation

Model 4: Evaluation scores			
Adequacy (3/4)	Compatibility (1/2)	Data handling (2/3)	Effectiveness (1/1)
Environment (1/1)	Information quality (2/3)	Information systems standards (1/1)	Security (2/3)
Service quality (1/1)	Structure (1/1)	System quality (2/3)	System use (1/1)
User satisfaction (1/1)	**Total score: 19/25**		

BPP scores		Model aims		Evaluation	BPP	Aims
Access (1/1)	Best value (3/4)	Combine				
Consultation (1/1)	Courtesy (4/6)	Communicate				
Customer impact (2/2)	Information (7/8)	Collaborate				
Openness and transparency (2/3)	Service standards (6/7)	Connect				
Redress (1/1)	**Total score: 27/33**	Represented	Not represented	76%	82%	75%

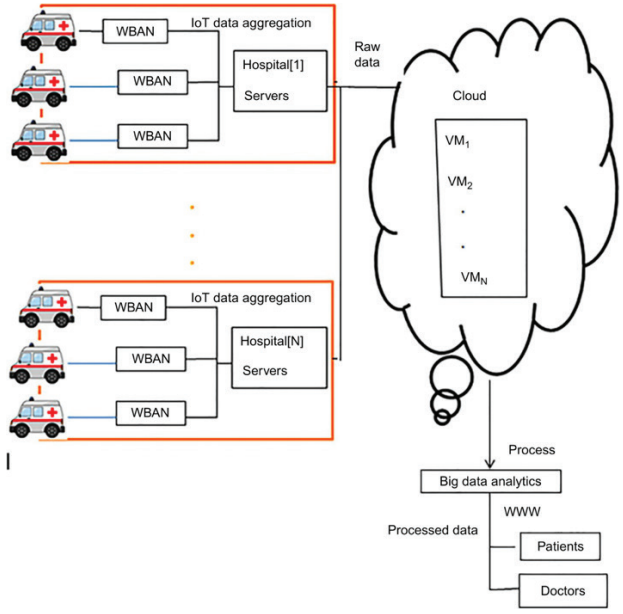
Source: Deebak, B.D., Memon, F.H., Cheng, X., Dev, K., Hu, J., Khowaja, S.A. et al., 2022, 'Seamless privacy-preservation and authentication framework for IoT-enabled smart eHealth systems', Sustainable Cities and Society 80, 103661. https://doi.org/10.1016/j.scs.2021.103661

BPP, Batho Pele Principles.

Appendix 12

TABLE 1-A12: Model 5 illustration and evaluation scores.

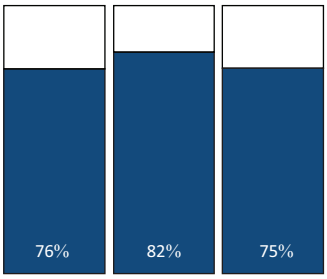
Model illustration



Evaluation

Model 5: Evaluation scores			
Adequacy (3/4)	Compatibility (1/2)	Data handling (2/3)	Effectiveness (1/1)
Environment (0/1)	Information quality (2/3)	Information systems standards (1/1)	Security (2/3)
Service quality (1/1)	Structure (1/1)	System quality (2/3)	System use (1/1)
User satisfaction (1/1)	**Total score: 19/25**		

BPP scores		Model aims	
Access (1/1)	Best value (3/4)	Combine	
Consultation (1/1)	Courtesy (4/6)	Communicate	
Customer impact (2/2)	Information (7/8)	Collaborate	
Openness and transparency (2/3)	Service standards (6/7)	Connect	
Redress (1/1)	**Total score: 27/33**	Represented	Not represented



Source: Dumka, A. & Sah, A., 2019, 'Smart ambulance system using concept of big data and internet of things', in N. Dey, A.S. Ashour, C. Bhatt, S.J. Fong, (eds.), *Healthcare Data Analytics and Management*, Academic Press, June 12–13, 2017, pp. 155–176. https://doi.org/10.1016/B978-0-12-815368-0.00006-3

WBAN, Wireless body sensor networks; IoT, Internet of Things; VM, Virtual Machine; WWW, World Wide Web; BPP, Batho Pele Principles.