Virtual health vs. In-Hospital Osteoarthritis Treatment in Australian Urban and Rural Settings

Medibank

COMPARATIVE LCA REPORT | NOVEMBER 2024

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This report compares the environmental impacts of different osteoarthritis treatment scenarios to guide sustainable decision-making for Medibank's future business practices. Utilising Life Cycle Assessment (LCA), we evaluated the environmental impacts of in-hospital total knee replacement (TKR) and Medibank's preventative "Better Knee Better Me" (BKBM) program, considering urban and rural settings.

LCA is a widely used and comprehensive framework for evaluating potential environmental impacts across the life cycle stages of a product or service. It involves assessing environmental impacts, identifying hotspots, facilitating peer comparisons, aiding in new designs, pinpointing areas for improvement, communicating benefits relative to competitors, and supporting sustainability certifications.

In this LCA study, the analysis looked at both rural and urban settings and considered various stages: such as virtual health, GP and clinic visits, surgery, and rehabilitation both at clinics and at home.

The primary objectives of this study were to comparatively assess the environmental impacts of virtual health and in-hospital treatment of knee osteoarthritis. The results can be used to:

1. Enhance comprehension of the environmental ramifications associated with virtual health and in-hospital osteoarthritis treatment options.
2. Investigate whether health management programs, beyond their evident health and financial benefits, could potentially yield reduced environmental impact compared to traditional in-hospital treatments.

The scope of this study:

- In this study, both midpoint and endpoint indicators were analysed.
- Midpoint indicators[2] evaluated the impact of scenarios on specific environmental issues, such as climate change or ocean acidification, while endpoint[3] indicators assessed environmental impacts and their implications for human health, biodiversity, and resource scarcity.
- This study utilised inventory data such as utilities, material usage, and waste treatment derived from publicly available literature.
- Medibank provided data relevant to the assessed scenarios, supplemented with publicly available literature and assumptions where primary data was limited.
- The study was conducted in accordance with ISO14040 and ISO14044, using the ReCiPe method.

[1] A full list of midpoint indicators assessed in this study is provided in Appendix B, [3] Further details on endpoint indicators are provided in Appendix C.

Executive summary

Key Findings:

- Virtual health scenarios consistently exhibited lower environmental impacts compared to in-hospital care across most indicators, with exception of human carcinogenic toxicity indicator which was higher in BKBM due to materials used and waste generated from the Welcome Pack.
- The BKBM program's welcome pack and the post-BKBM TKR emerged as environmental hotspots in virtual health scenarios, while surgery and rehabilitation were primary contributors in in-hospital care scenarios.
- In rural settings, lower environmental impacts of the virtual health scenario ranged from 33% to 55% of those observed in the in-hospital care scenario across midpoint categories, and 34% to 37% across endpoint categories (excluding human carcinogenic toxicity).
- In urban settings, the virtual health scenario demonstrated lower environmental impacts, ranging from 33% to 72% of those observed in the in-hospital care scenario across midpoint categories, and 36% to 39% across endpoint categories (excluding human carcinogenic toxicity).
- Variations in environmental impact between urban and rural areas arise from differences in transportation of participants/patients and medical staff.
- In-hospital care generally resulted in higher environmental impacts and waste generation compared to virtual health in both urban and rural settings. Primarily due to the materials, substances and utilities required during surgery and rehabilitation stages, and waste generated.
- Virtual health scenarios reduced waste generation by approximately 59% in comparison to in-hospital care scenarios. With 99% of the waste from in-hospital care scenarios originating from the surgery.
- Transportation to medical facilities significantly influenced key environmental indicators (global warming, ozone depletion, and fossil resource scarcity), particularly in rural settings, with virtual health showing more consistent benefits across both settings.

Recommendations:

- Strategies to promote virtual health or low-impact transport modes in rural areas could mitigate environmental impacts associated with in-hospital care.
- In the context of virtual health strategies, promoting virtual pre-program clinical eligibility checks by GPs via phone or online could mitigate the environmental impacts associated with traveling to the GP facility, particularly in rural settings.
- Gather primary data for and review the contents of the BKBM welcome packs to choose materials or products with lower environmental impacts and assess the validity of providing these products if customers already possess them, to avoid duplicity.
- Gathering primary data for surgery, in-hospital stay, and rehabilitation phases could enhance the study's accuracy. Similarly, collecting primary data for meal replacements in all scenarios is advisable.

In conclusion, this analysis indicated the environmental benefits of virtual health over in-hospital care for Medibank's future operations, while also emphasising the need for further research/data collection and the future development of tailored strategies to address specific environmental concerns.

Limitation of the study:

- This study primarily relied on publicly available generic data and assumptions to estimate the impacts of selected osteoarthritis treatment scenarios due to the lack of data specific to Medibank, its partners, and its members. The results showed significant differences between the virtual health and in-hospital care scenarios across most impact categories, indicating that uncertainties due to assumptions are unlikely to reverse the relative environmental performance of the scenarios. This limitation should be considered when communicating the results.

Project overview

Introduction

Medibank, a leading healthcare enterprise in Australia, provides private health insurance and a diverse range of health services. With a focus on flexibility in treatment options, they offer both traditional in-hospital care and virtual health alternatives to their members.

The current study aims to comprehensively understand the environmental impacts associated with both virtual health and in-hospital care. This Life Cycle Assessment (LCA) compares the environmental footprints of these approaches, using knee osteoarthritis treatment as a case study.

Medibank offers the Better Knee Better Me (BKBM) program, designed to manage knee osteoarthritis without resorting to total knee replacement (TKR) surgery, for eligible members.

This study applies Life Cycle Assessment (LCA) to compare the environmental impacts of virtual health and in-hospital treatment pathways for managing knee pain in patients with knee osteoarthritis. Specifically, the assessed scenarios included the virtual health delivery of Medibank's BKBM program and in-hospital care for TKR, both in urban and rural settings.

The objective of this study was to compare the environmental impacts associated with knee osteoarthritis treatment scenarios using one of the most widely used life cycle impact assessment methods, ReCiPe, and key environmental indicators, including global warming potential.

LCA Method

Goal and scope

The goal of this study is to comparatively assess the environmental impacts (aligned with ISO 14040:2006 and ISO14044:2006) and the amount of waste generated in virtual health and in-hospital treatment of knee osteoarthritis. The study intends to quantitatively assess the environmental advantages and disadvantages of virtual health compared to in-hospital treatments to support decision-making of Medibank's members. The intended audience for this study includes Medibank's decision-makers and its members. This study compares different knee pain treatment scenarios. The results are intended for use in comparative assertions within this study and may be disclosed to the public. However, they are not intended for comparison with results from other studies.

The study considered Medibank's "Better Knee, Better Me" (BKBM) program for virtual health and Total Knee Replacement (TKR) for in-hospital treatment.

In both cases, the urban and rural settings were considered. "An effective treatment of knee osteoarthritis for one person who intends to undergo TKR" was selected as the functional unit of this study. The effective treatments considered are as follows:

- Treatment with immediate TKR, referred as "In-hospital care," hereafter
- Participation in the BKBM program for one year, with a fraction of those who undergo TKR after the program, referred as "Virtual health," hereafter

The outcome of each treatment pathway is the participants' or patients' knee condition that no further major knee treatment is required. LCA was conducted to compare the environmental impacts of the following scenarios.

- Scenario 1: Virtual health in urban area
- Scenario 2: Virtual health in rural area
- Scenario 3: In-hospital care in urban area
- Scenario 4: In-hospital care in rural area

The reference flows of Scenarios 1 and 2 are BKBM program as well as TKR and rehabilitation for a fraction (30%) of BKBM participants, and those of Scenarios 3 and 4 are TKR and rehabilitation.

The study results can be used to:

1. Enhance comprehension of the environmental ramifications associated with virtual health and in-hospital osteoarthritis treatment options.
2. Investigate whether health management programs, beyond their evident health and financial benefits, could potentially yield reduced environmental impact compared to traditional in-hospital treatments.

It is important to note that this study assesses the environmental impacts of selected scenarios only. While these scenarios were chosen to be representative, individual participant/patient circumstances were not considered, therefore, the results should be viewed as indicative.

Virtual health Scenarios

(urban and rural areas)

Prior to joining the BKBM program, participants undergo pre-program checks, which include clinical eligibility verification, policy coverage confirmation, and screening surveys conducted via phone or internet. The electricity consumption and hardware required for internet access during these checks were accounted for in the LCA.

A specific subset of potential BKBM participants needs to undergo follow-up consultations with their general practitioner (GP) for further clinical eligibility checks. Based on recent participant survey data provided by Medibank, 65% of participants scheduled appointments with their GP for approval, while 15% contacted the clinic via phone to prompt the GP. Electricity consumption and materials used at the clinic during the GP visit and the transportation of participants and medical staff to the clinic were considered in the LCA.

The BKBM welcome pack comprises a Fitbit, resistance bands, digital weight scale, measuring tape, recipe book and printed information resources. The materials used for these items and freight transport of the goods were included in the LCA analysis.

Meal replacement was not considered in the LCA analysis due to insufficient information and expected variability in the types of meals being replaced.

Consultations during and after the program were assumed to take place online, with both participants and consultants/medical staff participating from their respective homes. The LCA accounted for the electricity consumption and hardware used during these consultations.

The difference between urban and rural settings is driving distance of BKBM participants and medical staff from their home to a GP facility and delivery distance of the BKBM welcome pack.

Utilities required for hospital overnight stays ("hospital stay") are factored into the in-hospital care scenarios. To maintain consistency, the equivalent duration of overnight stay at home ("home stay") was considered in the LCA. For energy consumption, it was assumed to affect only single-person households, and the fraction was considered.**

After participating in the BKBM program, only 30%* of participants who were initially willing to undergo TKR remained willing to proceed with the surgery (Gorniak et al., 2023). This fraction of participants was assumed to undergo TKR, and the associated impacts were included in the virtual health scenarios. The procedures, including pre-surgery, surgery, post-surgery, and rehabilitation, are assumed to be the same as those described in the in-hospital care scenarios in the next slide.

*The 30% fraction of participants who undergo TKR after the BKBM program was selected based on the assumed knee conditions of the participants. It was assumed that those who were initially willing to undergo surgery had similar knee conditions (e.g., degree of pain) to those who receive surgery. Participants who were initially unsure or not willing to undergo surgery likely had less severe conditions, so including them could misrepresent the effectiveness of the BKBM program. Therefore, 30% was conservatively chosen (as opposed to 16% of all participants, regardless of initial willingness).

**Data source: (ABS 2021) Census of Population and Housing: Housing data summary, 2021, https://www.abs.gov.au/statistics/people/housing/housing-census/2021

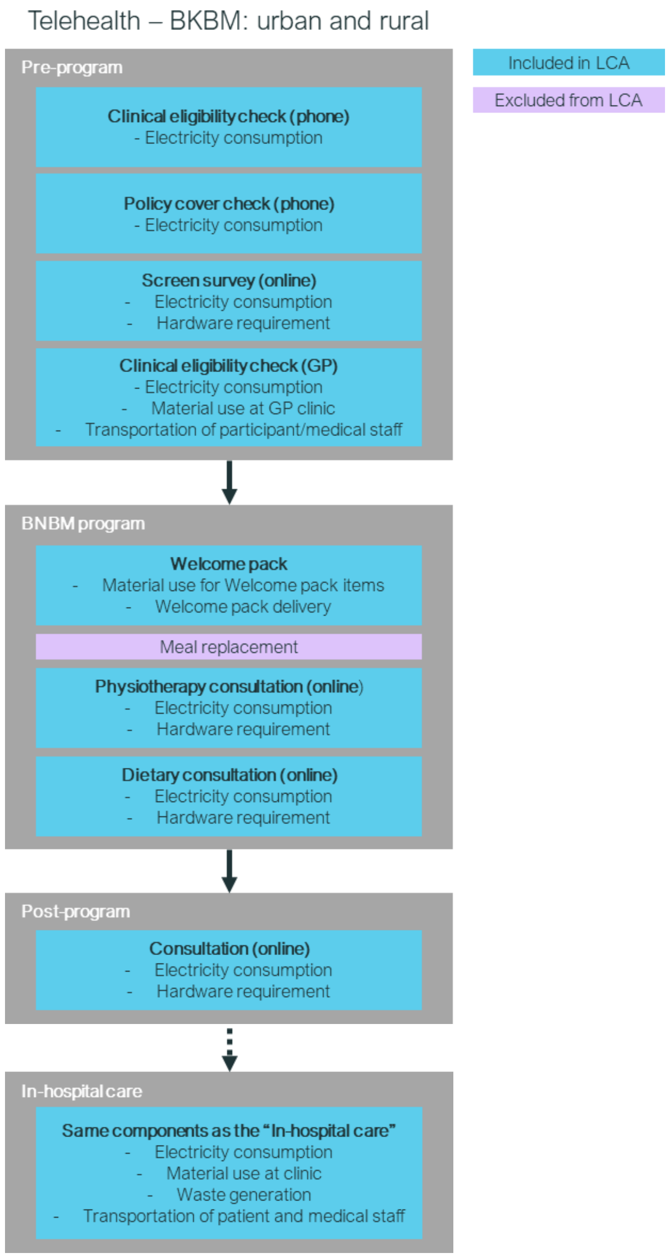


Figure 1: System flow - virtual health

In-hospital care scenarios

(urban and rural areas)

Pre-admission clinic procedures include blood tests, X-rays and urine tests conducted at a clinic or hospital. The LCA accounts for patient and medical staff transportation, facility usage, utilities and materials required for the tests, and generated waste.

Total knee replacement (TKR) surgery was assumed to occur at a hospital. The LCA considered substances, materials and utilities usage, waste generation during the surgery, and transportation of patients and medical staff.

Post-surgery procedures include medications and hospital visits for reviews. The LCA includes medication usage, hospital facility use and transportation of patients and medical staff.

Transport of consumables used at medical facilities, such as personal protective equipment was not considered, due to lack of data and anticipated insignificant impacts (Delaie et al. 2023). Production and transport of medical machines used at medical facilities were also excluded from the LCA, due to their expected insignificant environmental impacts when allocated to a single case of use, considering the number of times the device is used during its lifespan (Delaie et al. 2023).

Various rehabilitation options were considered, including inpatient (36% of TKR patients), outpatient (22.5%), and home-based (34%) rehabilitation, with the remainder assumed to self-manage. The LCA considered utilities required for hospital overnight stays ("hospital stay") for inpatient rehabilitation and the equivalent duration of overnight stay at home ("home stay") for other rehabilitation options.

Post-surgery hospital readmission was excluded from the LCA analysis due to insufficient information on readmission procedures and the low 28-day readmission rate (<5%).

The difference between urban and rural settings is driving distance of patients and medical staff from their home to a clinic/hospital.

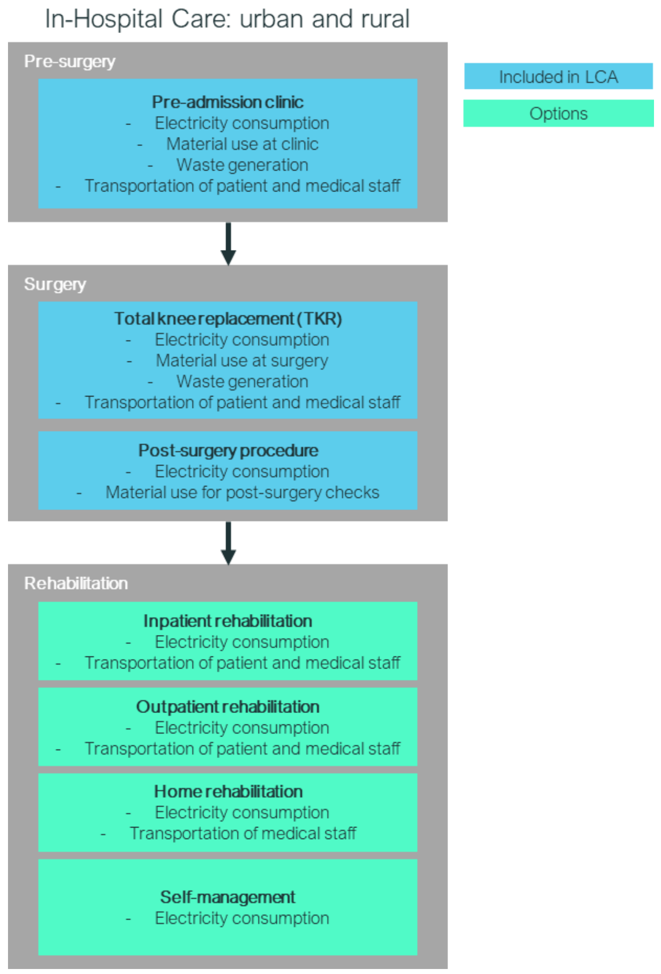


Figure 2: System flow – in-hospital care

System boundary – Inclusions

The LCA includes:

- Utilities required for virtual health consultations.
- Utilities required for clinic and hospital operations including facility and medical device usage.
- Utilities required for hospital overnight stays ("hospital stay") and the equivalent duration of overnight stay at home ("home stay") for scenarios that do not require a hospital stay.
- Transportation of BKBM participants/TKR patients and medical staff.
- Equipment used for virtual health consultations.
- Equipment used in the BKBM program, including the welcome pack, and end-of-life treatment.
- Equipment required for in-person consultation and surgery at clinics/hospitals and end-of-life treatment.
- Substances employed for treatment, including anesthetic gases and drugs.

Cut-off criteria and exclusions

It is common practice in LCA/LCI protocols to propose exclusions for inputs and outputs that are expected to have insignificant contributions to the overall impacts. The objective of this study is to comparatively assess the impacts associated with different knee pain treatments. To reduce overall uncertainty, materials and processes common across all scenarios were excluded when specific data were unavailable; however, no specific cut-off criteria were established in this study. The following are excluded:

- Meal replacements provided by the BKBM program and the equivalents for other scenarios, due to lack of data on meals replaced - the meals replaced could considerably vary depending on individuals.
- Meals provided during the hospital stay and those of the corresponding home stay were excluded from the analysis due to insufficient data and the expected significant variability among individuals.
- Impacts caused by cleaning of the clinic/hospital, storage of patient data on a secure computer server, stay in a conventional hospital ward, and hospital construction were not included. Cleaning of the home space and construction of the home were not considered.
- The electricity required for charging devices provided within the BKBM program, such as Fitbits and digital scales, was excluded due to uncertainty in usage frequency and the anticipated negligible amount of electricity consumed.
- Transport of consumables used at medical facilities, such as personal protective equipment, due to lack of data and anticipated negligible impacts considering the weight of the equipment.
- Production and transport of medical machines used at medical facilities, due to their expected insignificant environmental impacts when allocated to a single case of use, considering the number of times the device is used during their lifespan.
- Materials and utilities required for rehabilitation due to lack of data on rehabilitation program for any mode of rehabilitation.
- Impacts resulting from readmission to hospitals after surgery due to the low readmission rates (< 5%) and lack of information on treatment during readmission.

Assumptions and limitations

To make the scenarios comparable, the outcomes of each treatment scenario are assumed to be similar. However, it is important to note that there is uncertainty in the outcome of the treatments studied in this LCA. Multiple potential outcomes are possible depending on the participants/patients.

Scenario 1:

Virtual health - Medibank's Better Knee Better Me program in urban area

- Program participants and medical staff were assumed to travel 5 km to a GP office by passenger vehicles (medium-size petrol cars) when visiting facilities.
- The distance to landfill for waste treatment was assumed to be 50 km.
- The staffing levels at the GP were assumed as follows:
  - 3 staff per 8 patients per day
- This study used generic data from publicly available sources and assumptions in instances where specific data was not provided by Medibank. This includes data related to materials used for items provided as part of the BKBM welcome pack.
- This study is limited to assessing the environmental impacts of a 1-year BKBM program, including a fraction of participants who undergo TKR after the program. It does not account for the environmental impacts of any subsequent treatments that some participants may require.
- This study utilised inventory data such as utilities, material usage, and waste treatment derived from publicly available literature[4].
- 30% of the BKBM participants remained willing to undergo TKR after the program.

Scenario 2:

Virtual health - Medibank's Better Knee Better Me program in rural area

- Program participants and medical staff were assumed to travel 20 km to a GP office by passenger vehicles (medium-size petrol cars) when visiting facilities.
- The distance to landfill for waste treatment was assumed to be 100 km.
- The staffing levels at the GP were assumed as follows:
  - 3 staff per 8 patients per day
- This study used generic data from publicly available sources and assumptions in instances where specific data was not provided by Medibank. This includes data related to materials used for items provided as part of the BKBM welcome pack.
- This study is limited to assessing the environmental impacts of a 1-year BKBM program, including a fraction of participants who undergo TKR after the program. It does not account for the environmental impacts of any subsequent treatments that some participants may require.
- This study utilised inventory data such as utilities, material usage, and waste treatment derived from publicly available literature[4].
- 30% of the BKBM participants remained willing to undergo TKR after the program.

Assumptions and limitations

To make the scenarios comparable, the outcomes of each treatment scenario are assumed to be similar. However, it is important to note that there is uncertainty in the outcome of the treatments studied in this LCA. Multiple potential outcomes are possible depending on the participants/patients.

Scenario 3: In-hospital care - Total Knee Replacement surgery in urban area

- Program participants and medical staff were assumed to travel 5 km to a clinic and therapist office by passenger vehicles (medium-size petrol cars) when visiting facilities.
- Program participants and medical staff were assumed to travel 10 km to a hospital by passenger vehicles (medium-size petrol cars) when visiting facilities.
- The distance to landfill for waste treatment was assumed to be 50 km.
- The staffing levels at physiotherapy and medical clinic/hospital were assumed as follows:
  - Physiotherapy: 2 staff per 8 patients per day
  - Medical clinic/hospital: 3 staff per 8 patients per day
- Post-surgery medications were assumed to be taken as prescribed - no disposal of drugs was considered.
- TKR patients who remained in the hospital after surgery were assumed to undergo inpatient rehabilitation during their hospital stay.
- Outpatient rehabilitation involved the assumed visits to a facility in the community using passenger vehicles once a week.
- Home rehabilitation scenario was aligned with Medibank's Rehab at Home program*.
- Equipment used for rehabilitation was not accounted for, due to lack of specific information.
- Different modes of rehabilitation were considered by applying weighted averages.
- Impacts resulting from readmission to hospitals after surgery were excluded due to the low readmission rates (< 5%) and lack of information on treatment during readmission.
- This study used generic data from publicly available sources and assumptions in instances where specific data was not provided by Medibank. This includes data related to TKR surgery and anesthesia.
- This study evaluates the environmental impacts of in-hospital care for a single TKR surgery. It does not account for the environmental impacts of any subsequent treatments that some participants may require.
- This study utilised inventory data such as utilities, material usage, and waste treatment derived from publicly available literature[4].

*Medibank's Rehab at Home program: https://www.medibank.com.au/health-support/health-services/medibank-at-home/rehab-at-home

Assumptions and limitations

To make the scenarios comparable, the outcomes of each treatment scenario are assumed to be similar. However, it is important to note that there is uncertainty in the outcome of the treatments studied in this LCA. Multiple potential outcomes are possible depending on the participants/patients.

Scenario 4: In-hospital care - Total Knee Replacement surgery in rural area

- Program participants and medical staff were assumed to travel 20 km to a clinic and therapist office by passenger vehicles (medium-size petrol cars) when visiting facilities.
- Program participants were assumed to travel 100 km to a hospital by passenger vehicles (medium-size petrol cars) when visiting facilities.
- Medical staff were assumed to travel 20 km to a hospital by passenger vehicles (medium-size petrol cars) when visiting facilities.
- The distance to landfill for waste treatment was assumed to be 100 km.
- The staffing levels at physiotherapy and medical clinic/hospital were assumed as follows:
  - Physiotherapy: 2 staff per 8 patients per day
  - Medical clinic/hospital: 3 staff per 8 patients per day
- Post-surgery medications were assumed to be taken as prescribed - no disposal of drugs was considered.
- TKR patients who remained in the hospital after surgery were assumed to undergo inpatient rehabilitation during their hospital stay.
- Outpatient rehabilitation involved the assumed visits to a facility in the community using passenger vehicles once a week.
- Home rehabilitation scenario was aligned with Medibank's Rehab at Home program.
- Equipment used for rehabilitation was not accounted for, due to lack of specific information.
- Different modes of rehabilitation were considered by applying weighted averages.
- Impacts resulting from readmission to hospitals after surgery were excluded due to the low readmission rates (< 5%) and lack of information on treatment during readmission.
- This study used generic data from publicly available sources and assumptions in instances where specific data was not provided by Medibank. This includes data related to TKR surgery and anesthesia.
- This study evaluates the environmental impacts of in-hospital care for a single TKR surgery. It does not account for the environmental impacts of any subsequent treatments that some participants may require.
- This study utilised inventory data such as utilities, material usage, and waste treatment derived from publicly available literature[4].

*Medibank's Rehab at Home program: https://www.medibank.com.au/health-support/health-services/medibank-at-home/rehab-at-home

Description of allocation choices

ISO 14044 stipulates that due consideration must be given to the fact that industrial processes often yield more than one product, and they recycle intermediate or discarded products as raw materials, thus presenting the need for allocation procedures. The standard further sets out the following rules:

- Wherever possible, allocation should be avoided,
- Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned based on underlying physical relationships,
- Where physical relationships alone cannot be established, allocation can be done based on economic relationships.

Since there is a single output in all the scenarios considered in this study, allocation was not applied. No open-source data this study referred to mentioned the use of allocation, except Thiel et al. (2017), where the impacts of reusable surgical linens were allocated based on the estimated lifespan of the materials.

Method overview

To assess environmental impacts, the quantity of materials and utilities involved in each scenario was estimated using data provided by Medibank and data from publicly available information, and background data sourced from LCA databases, AusLCI v1.42 and ecoinvent v3.9.1.

The potential environmental impacts were calculated by multiplying the quantity of materials and utilities by corresponding environmental impact factors provided by ReCiPe 2016 v1.08 (H) method. A simplified formula to quantify environmental impacts and key characteristics of this study are shown below.

The amount of waste considered only foreground data and was estimated by summing wasted generated in each stage of the scenarios.

Inventory data		Impact assessment method		Environmental impacts
Physical data *(e.g., kWh electricity, kg material used)*	x	Environmental impact factors	=	e.g., Global warming potential (kg CO_2-eq.)

Life cycle inventory

Foreground data:

Medibank-specific data, such as details of the BKBM program, length of hospital stay after TKR surgery, and proportion of TKR patients for each mode of rehabilitation, were provided by Medibank. However, this specific data provided were insufficient for conducting the LCA.

To address data gaps, online searches were conducted, and publicly available literature data were used. When data were unavailable, general assumptions were used. These include travel distances of participants, patients, and medical staff from their respective homes to medical facilities and duration of in-person consultations. Therefore, the results should be regarded as a general indication rather than specific to Medibank members. The data sources referenced in this LCA study are listed in Appendix P and complete citations are available in Appendix Q.

Background data:

LCA software, SimaPro (v9.4.0.1), was used for the calculations, using AusLCI (version 1.42) and ecoinvent (version 3.9.1) as the source for background generic data.

Life cycle impact assessment (LCIA) method

The life cycle impact assessment method used was ReCiPe 2016 v1.08 (H)*. ReCiPe was chosen due to its wide acceptance across diverse fields for calculating potential impacts and its comprehensive coverage of various environmental impact categories, which facilitates a thorough assessment of environmental impacts. ReCiPe includes 18 midpoint indicators and 3 endpoint indicators as listed in Appendices B and C.

The extensive coverage of ReCiPe's midpoint impact categories enables a comprehensive assessment of potential environmental impacts, facilitating rigorous environmental assessment and supporting the realisation of potential trade-offs between different types of impacts. However, the high number of impact categories can make it challenging to discern which scenario has a lower environmental impact, especially when the results of each indicator appear contradictory. Endpoint indicators help reduce the number of categories considered while taking all the midpoint categories into account, simplifying comparisons of the scenarios' environmental performance. However, it is important to note that during the conversion from the midpoint to endpoint indicators, additional uncertainties are unavoidable, due to the increased assumptions used in the LCIA method.

The midpoint and endpoint results and their interpretation across the four scenarios considered in this study are provided in the next slides.

*ReCiPe: https://pre-sustainability.com/articles/recipe/

Critical review

The critical review of this comparative LCA to assess compliance against ISO 14044 has been undertaken by Anna Boyden of Lifecycles. The review of this study was conducted to reduce the likelihood of misunderstandings or negative effects on external interested parties when disclosed to the public. While a panel review is technically required for comparative assertions intended to be disclosed to the public, one independent expert was chosen for the review of the study. This approach was deemed adequate given the study's complexity and the fact that the comparisons are limited to Medibank services, with no intention for external comparisons beyond this specific study.

LCA Results

Midpoint impacts

Comparison of LCA midpoint results across scenarios, Virtual health – Urban and Rural, and In-hospital care – Urban and Rural.

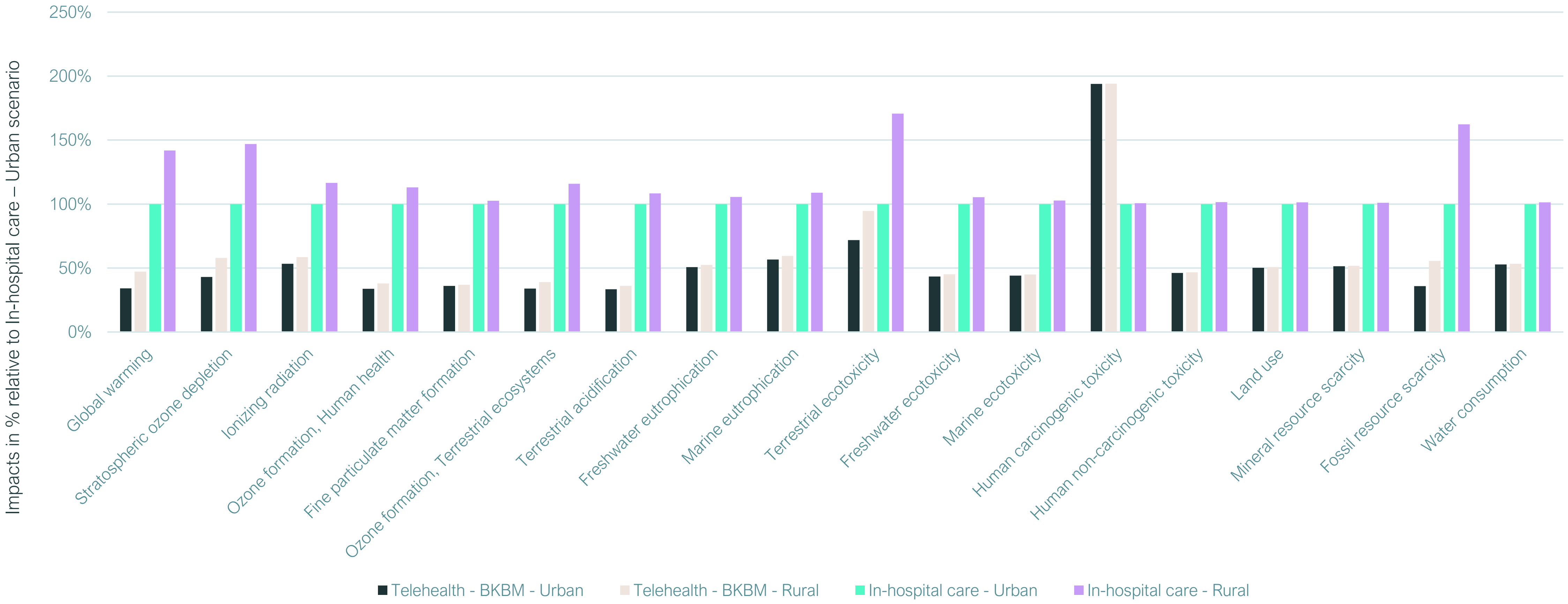


Figure 3: Results – midpoint impacts

The chart shows the impacts of each scenario relative to that of the “In-hospital care – Urban” scenario in %.

Midpoint impacts – Numerical results

Table 1: Results – midpoint impacts

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	1.9E+02	4.8E-05	2.2E+00	4.4E-01	2.6E-01	4.5E-01	7.6E-01	1.8E-02	2.9E-02	3.5E+02	2.6E+00	3.4E+00	1.3E+01	4.5E+01	4.0E+00	1.4E+00	3.3E+01	3.7E+00
Virtual health - BKBM - Rural	2.6E+02	6.5E-05	2.4E+00	4.9E-01	2.6E-01	5.1E-01	8.1E-01	1.9E-02	3.0E-02	4.7E+02	2.7E+00	3.5E+00	1.3E+01	4.5E+01	4.0E+00	1.5E+00	5.2E+01	3.7E+00
In-hospital care - Urban	5.6E+02	1.1E-04	4.0E+00	1.3E+00	7.1E-01	1.3E+00	2.3E+00	3.6E-02	5.1E-02	4.9E+02	6.0E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	9.3E+01	7.0E+00
In-hospital care - Rural	7.9E+02	1.7E-04	4.7E+00	1.5E+00	7.3E-01	1.5E+00	2.5E+00	3.8E-02	5.5E-02	8.4E+02	6.3E+00	8.0E+00	6.7E+00	9.8E+01	8.1E+00	2.8E+00	1.5E+02	7.1E+00

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Midpoint impacts – Numerical results – Mode of rehabilitation

Table 2: Results – midpoint impacts – mode of rehabilitation

	GWP kg CO2 eq	ODP kg CFC11 eq	IRP kBq Co-60 eq	HOFP kg NOx eq	PMFP kg PM2.5 eq	EOFP kg NOx eq	TAP kg SO2 eq	FEP kg P eq	MEP kg N eq	TETP kg 1,4-DCB	FETP kg 1,4-DCB	METP kg 1,4-DCB	HTPc kg 1,4-DCB	HTPnc kg 1,4-DCB	LOP m2a crop eq	SOP kg Cu eq	FFP kg oil eq	WCP m3
Urban																		
Rehabilitation - inpatient program	7.91E+02	9.98E-05	2.36E-01	1.95E+00	1.05E+00	1.95E+00	3.38E+00	8.89E-03	4.95E-02	4.56E+01	8.78E-01	1.16E+00	1.73E-01	5.55E+00	2.28E+00	5.95E-03	1.23E+02	7.59E+00
Rehabilitation - outpatient program	3.16E+01	1.61E-05	2.35E-01	3.70E-02	1.38E-02	4.12E-02	5.61E-02	2.91E-03	1.30E-02	3.60E+01	1.11E-01	8.72E-02	6.46E-02	2.39E+00	1.13E+00	4.82E-03	7.54E+00	1.50E+00
Rehabilitation - at home	3.25E+01	1.63E-05	2.39E-01	3.65E-02	1.31E-02	4.10E-02	5.46E-02	2.92E-03	1.31E-02	3.82E+01	1.13E-01	8.77E-02	6.48E-02	2.40E+00	1.13E+00	5.00E-03	7.83E+00	1.50E+00
Self-management	8.28E+00	1.09E-05	1.70E-01	1.89E-02	1.11E-02	1.92E-02	3.47E-02	2.72E-03	1.26E-02	2.64E+00	7.99E-02	6.52E-02	6.03E-02	2.26E+00	1.12E+00	2.01E-03	1.82E+00	1.49E+00
Rural																		
Rehabilitation - inpatient program	8.02E+02	1.02E-04	2.67E-01	1.96E+00	1.05E+00	1.96E+00	3.39E+00	8.98E-03	4.97E-02	6.16E+01	8.92E-01	1.17E+00	1.76E-01	5.61E+00	2.29E+00	7.30E-03	1.26E+02	7.59E+00
Rehabilitation - outpatient program	9.92E+01	3.14E-05	4.30E-01	8.57E-02	1.91E-02	1.02E-01	1.11E-01	3.48E-03	1.43E-02	1.36E+02	2.03E-01	1.50E-01	7.73E-02	2.77E+00	1.16E+00	1.32E-02	2.44E+01	1.53E+00
Rehabilitation - at home	9.26E+01	2.99E-05	4.12E-01	7.98E-02	1.78E-02	9.46E-02	1.03E-01	3.43E-03	1.42E-02	1.27E+02	1.95E-01	1.43E-01	7.61E-02	2.73E+00	1.16E+00	1.25E-02	2.28E+01	1.52E+00
Self-management	8.28E+00	1.09E-05	1.70E-01	1.89E-02	1.11E-02	1.92E-02	3.47E-02	2.72E-03	1.26E-02	2.64E+00	7.99E-02	6.52E-02	6.03E-02	2.26E+00	1.12E+00	2.01E-03	1.82E+00	1.49E+00

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Midpoint interpretation

The interpretation here assumes that the effectiveness of the knee treatment in each scenario is equivalent.

In urban settings, the virtual health scenario demonstrated lower environmental impacts than the in-hospital care scenario for all midpoint indicators, except for human carcinogenic toxicity. The virtual health scenario's impacts ranged from 37% to 71% of those observed in the in-hospital care scenario across all midpoint categories besides human carcinogenic toxicity.

Surgery and rehabilitation stages were the primary contributors in most categories for the in-hospital care scenario, except for freshwater ecotoxicity, marine ecotoxicity, and human non-carcinogenic impacts, where the pre-surgery examination stage also contributed, primarily due to the materials and substances required for the examinations. The impacts of each rehabilitation mode shown in Table 2 suggest the impacts caused by the rehabilitation stage could vary significantly depending on the mode of rehabilitation undertaken.

For the virtual health scenario, the highest impacts were caused by the potential TKR after the BKBM program for most of the impact categories. The material usage and waste treatment associated with items included in the BKBM welcome pack also led to higher impacts in the categories of terrestrial ecotoxicity and human carcinogenic toxicity. The assumption was made that the BKBM welcome pack would only be used for its intended purpose during the duration of the BKBM program. The influences of this assumption were examined in the sensitivity analysis section.

In rural settings, similar trends to those observed in urban settings were noted. The virtual health scenario exhibited lower environmental impacts than the in-hospital care scenario, accounting for 35% to 55% of the impacts of the in-hospital care scenario across all midpoint categories, except for human carcinogenic toxicity. The primary contributors were similar to those in the urban settings.

In comparing urban and rural settings, the impact of the transportation of participants/patients and medical staff was the differentiating factor. In virtual health scenarios, regional differences were up to around 30% across all the midpoint categories, while in in-hospital care scenarios, differences of up to around 40% were observed. Impact categories most affected by transport distances were global warming potential, stratospheric ozone depletion, terrestrial ecotoxicity, and fossil resource scarcity for both virtual health and in-hospital care scenarios.

The impacts of different rehabilitation modes are presented in Table 2. The weighted averages of each mode's impact, based on the proportion of patients undergoing each rehabilitation mode, were included in the total impacts. The impacts were the highest for the inpatient rehabilitation for most impact categories for both urban and rural settings. The exceptions were Ionizing radiation, Terrestrial ecotoxicity, and Mineral resource scarcity in the rural region, where the outpatient and home rehabilitation caused higher impacts due to additional patient's travel to medical facilities and/or medical staff's travel to patient's home.

Endpoint impacts

Comparison of LCA endpoint results across scenarios, Virtual health – Urban and Rural, and In-hospital care – Urban and Rural.

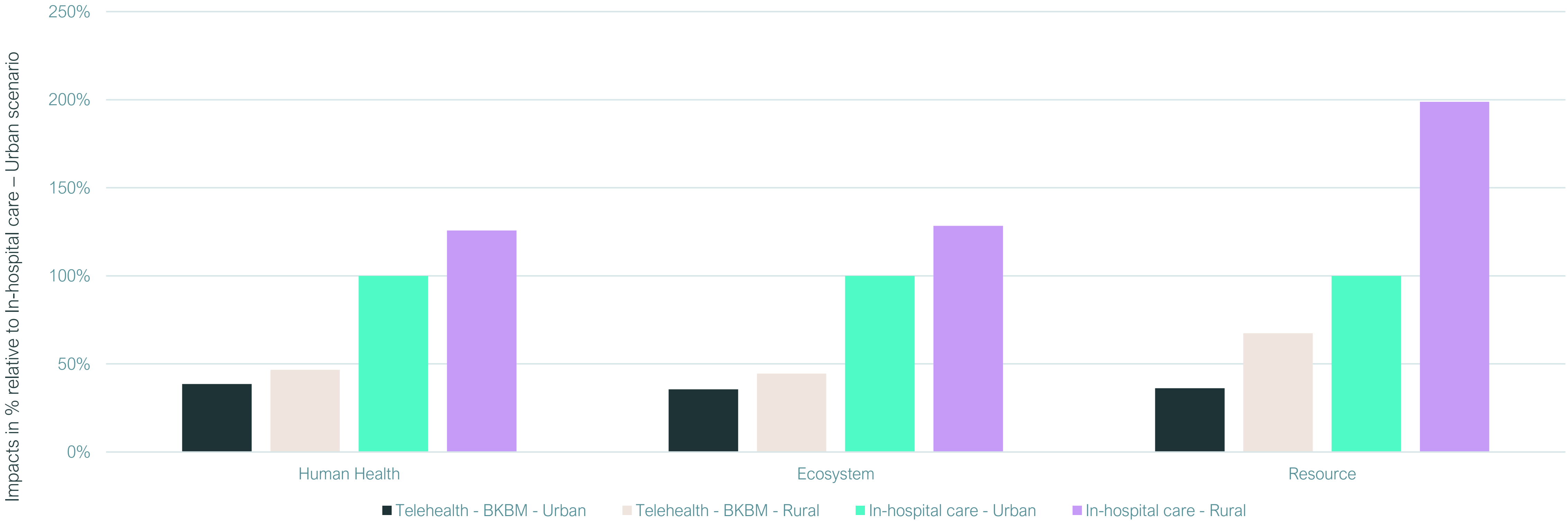


Figure 4: Results – endpoint impacts

The chart shows the impacts of each scenario relative to that of the “In-hospital care – Urban” scenario in %.

Endpoint impacts – Numerical results

Table 3: Results – endpoint impacts

	HH	EQ	RA
	DALY	species.yr	USD2013
Virtual health - BKBM - Urban	3.9E-04	8.7E-07	9.6E+00
Virtual health - BKBM - Rural	4.8E-04	1.1E-06	1.8E+01
In-hospital care - Urban	1.0E-03	2.4E-06	2.7E+01
In-hospital care - Rural	1.3E-03	3.1E-06	5.3E+01

HH: Damage to human health, ED: Damage to ecosystems, RA: Damage to resource availability

Endpoint interpretation

The interpretation here assumes that the effectiveness of the knee treatment in each scenario is equivalent.

In urban settings, the virtual health scenario demonstrated lower environmental impacts compared to the in-hospital care scenario. The virtual health scenario's impacts ranged from 39% to 42% of those observed in the in-hospital care scenario across all endpoint categories.

In Rural settings, the virtual health scenario demonstrated lower environmental impacts compared to the in-hospital care scenario. The virtual health scenario's impacts ranged from 37% to 40% of those observed in the in-hospital care scenario across all endpoint categories.

In comparing urban and rural settings, the impact of transporting participants/patients and medical staff was the distinguishing factor. In virtual health scenarios, regional differences were between 16%-42%, while in in-hospital care scenarios, differences were between 20%-49%. Notably, the highest differences were observed in the resource category.

Environmental impact – hotspot analysis – Midpoint

Heat maps to visualise hotspots of each scenario are provided in Appendix E-H.

The TKR undergone by a fraction of BKBM participants was identified as the environmental impact hotspot for most midpoint categories in case of the virtual health scenarios in urban and rural settings. The notable impacts were contributed during the surgery and rehabilitation stages. The main contributing factors during these stages are discussed in more detail in the next slide. The impact categories where the BKBM welcome pack appeared to significantly contribute include freshwater eutrophication, ionizing radiation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, human carcinogenic toxicity, human non-carcinogenic toxicity, land use, and mineral resource scarcity in the virtual health scenarios in both urban and rural settings*.

Due to the lack of detailed information on the materials used, manufacturing processes, transport mode and distance, and the end-of-life treatment methods of the items included in the welcome pack, assumptions were made to estimate the impacts of these goods, leading to potential inaccuracies in the results. Therefore, a more precise assessment with detailed data is recommended for a more realistic evaluation.

To mitigate the impacts linked to the welcome pack, the items included in the welcome pack could be evaluated for their necessity within the program to eliminate unnecessary material use. Customisation options could be offered for participants who already possess similar products, reducing duplication.

Additionally, materials used for these products could be substituted with less environmentally impactful alternatives. Information typically provided on paper could be delivered electronically to reduce paper usage and associated environmental impacts.

*Numerical results of midpoint hotspot analysis are provided in Appendix E-H.

Environmental impact – hotspot analysis – Midpoint (continued)

Surgery and rehabilitation were the highest contributors for the in-hospital care scenario in both urban and rural settings for most of the midpoint categories.

For the surgery stage, impacts associated with TKR operation were the dominating contributor to all impact categories followed by anaesthesia, X-ray, utilities associated with hospital space use were considered. The impacts related to consumables such as PPE, patient and staff travel, and waste treatment were relatively insignificant.

The rehabilitation stage in both urban and rural settings of the in-hospital care scenarios appeared to have the highest contribution across multiple categories, including global warming, ozone formation-human health, fine particulate matter formation, ozone formation-terrestrial ecosystems, terrestrial acidification, fossil resource scarcity, and water consumption*.

Hospital stays for patients undergoing inpatient rehabilitation were the primary contributors to these categories due to the high utilities consumption associated with hospital operations. It should be noted that the use of publicly available literature data to estimate the impacts related to hospital stays, due to unavailability of specific data at Medibank, may have led to inaccuracies in the results.

Nevertheless, promoting home-based rehabilitation could potentially reduce the impact of the rehabilitation stage, given that hospital utilities consumption is generally higher than that of residential homes. In rural settings, while hospital stays remain the dominating contributor to the impacts, the significance of its contribution was reduced compared to the urban setting due to increased impacts associated with travel to the facility for outpatient rehabilitation and therapist visits to homes for at-home rehabilitation options.

In the absence of data on actual transport modes and travel distances, the analysis assumed travel by medium-sized petrol car and a travel distance of 20 km for these rehabilitation options. Assessing the impacts with actual data on travel distance and transport mode is highly recommended for more precise results. Mitigating travel-related impacts could involve switching to lower-emission transport modes or provision of virtual consultations.

The impacts during the pre-surgery stage generally were lower than those of other stages across most midpoint impact categories for the in-hospital care scenarios in both urban and rural settings. However, notable exceptions were observed in freshwater ecotoxicity, marine ecotoxicity, and human non-carcinogenic toxicity. These impacts were primarily contributed by materials and substances used during pre-surgery examinations[7].

*Numerical results of midpoint hotspot analysis are provided in Appendix E-H.

Environmental impact – hotspot analysis – Endpoint

Heat maps to visualise hotspots of each scenario are provided in Appendix I.

The TKR undergone by a fraction of the BKBM participants emerged as the environmental impact hotspot for endpoint indicators in the virtual health scenarios for urban and rural settings.

In the in-hospital care scenarios, the rehabilitation stage emerged as the primary contributor in both urban and rural settings*. Hospital stays for patients undergoing inpatient rehabilitation were the primary contributors to all endpoint indicators due to the high utilities consumption associated with hospital operations. It should be noted that the use of publicly available literature data to estimate the impacts related to hospital stays, due to unavailability of specific data at Medibank, may have led to inaccuracies in the results. Similar to the midpoint analysis, the BKBM welcome pack and home stay in the virtual health scenarios and the surgery in the in-hospital care scenarios also contributed across the endpoint indicators.

The virtual health scenario in the rural setting exhibited higher compared to the urban setting across the endpoint categories, attributed to the travel of participants and medical staff to the GP facility. Like the midpoint hotspot analysis, obtaining more precise data regarding travel distance and mode of transport will enhance assessment accuracy. Considering the use of lower-impact transport modes will aid in mitigating the impact of this stage.

In the in-hospital care scenarios, regardless of the region, the rehabilitation stage emerged as the highest contributor. This was mainly attributed to the substantial impacts associated with hospital stays for inpatient rehabilitation, mirroring the findings of the midpoint analysis. As more patients choose alternative modes of rehabilitation, such as outpatient or at-home options, the overall impacts of in-hospital care scenarios could potentially decrease.

In comparing urban and rural settings, the difference between the regions in the virtual health scenario ranged from 19% for human health to 71% for resource availability. This disparity was influenced by the travel distance from the BKBM participants' and medical staff's homes to the medical facilities. For the in-hospital care scenarios, the difference ranged from 25% for Human health to 95% for Resource availability. Comparable to the virtual health scenarios, the differing factor was the travel distance of patients and medical staff. However, in the in-hospital care scenarios, the number of trips involved was higher than in the virtual health scenarios, resulting in a larger discrepancy. Using lower-impact transport modes will aid in mitigating impacts for the rural regions.

*Numerical results of endpoint hotspot analysis are provided in Appendix I.

Waste generation

The difference between the urban and rural settings considered in this study was transport distance, hence, the amount of waste generation was identical regardless of the region in this study.

The virtual health scenario reduced waste generation by about 60% compared to in-hospital care scenarios.

In the virtual health scenario, waste was primarily associated with the post-BKBM TKR and BKBM welcome pack. The high waste generation related to the BKBM welcome pack is because the BKBM welcome pack was assumed to be exclusively used for its intended purpose, with participants not requiring these items otherwise. On the other hand, hardware such as virtual health equipment, e.g., laptops, was assumed to primarily serve other purposes such as remote working and personal communication. Consequently, only a small proportion of associated wastes were allocated to the BKBM program.

Since the detailed information about the items included in the BKBM welcome pack was not available, the mass and type of material used for each item was assumed based on commonly available similar products and recycling of the material was not considered.

To reduce the amount of waste in the virtual health scenarios, the items included could be evaluated for their necessity within the program. For example, customization options could be offered for participants who already possess similar products, reducing duplication.

In in-hospital care scenarios, 99% of the waste originated from the surgery, including plastic wrappers, disposable surgical linens and personal protective equipment.

Waste generation in the virtual health and in-hospital care scenarios

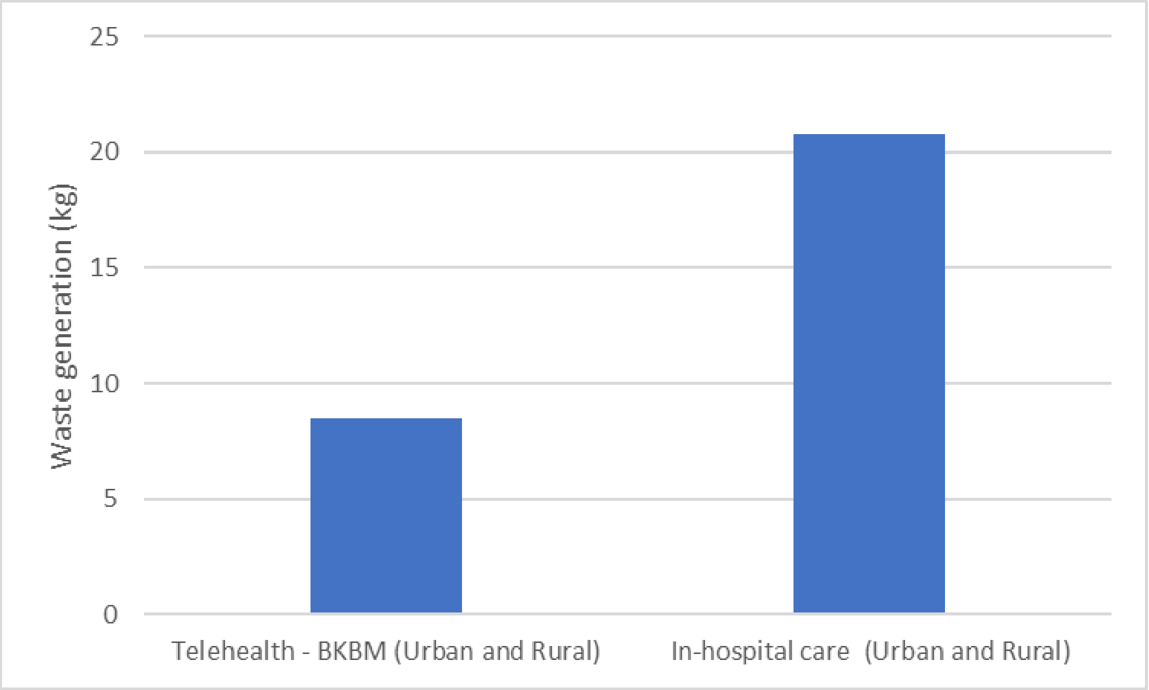


Figure 5: Results – waste generation

Conclusion and next steps

Conclusion

In both urban and rural settings, virtual health generally had lower environmental impacts than in-hospital care, except for human carcinogenic toxicity linked to the BKBM welcome pack material.

In the virtual health scenarios, it may be worthwhile to address the environmental impact of the BKBM welcome pack by conducting a more detailed assessment. This could involve obtaining specific data about the materials used for the items included in the welcome pack and their end-of-life treatment methods. Such efforts will facilitate more accurate analysis and help to mitigate the environmental impacts of the virtual health scenarios.

In the virtual health scenarios, promoting virtual pre-program clinical eligibility checks by GPs via phone or online could help eliminate the environmental impacts associated with traveling to the GP facility, particularly in rural settings.

The increased environmental impacts observed in rural settings in the in-hospital care scenarios, primarily attributed to the extended travel distances of participants/patients and medical staff, highlight significant opportunities for environmental impact mitigation through the promotion of virtual health options in rural areas.

In the in-hospital care scenarios, the surgery and rehabilitation stages stand out as major contributors to the environmental footprint.

The virtual health scenario significantly reduces waste compared to in-hospital care for both urban and rural settings.

Limitations of this study

As outlined in the cut-off and exclusions section, as well as the assumptions and limitations section, this study primarily relied on publicly available generic data and assumptions to estimate the impacts of selected osteoarthritis treatment scenarios due to the lack of data specific to Medibank, its partners, and its members. Data sources for each item are detailed in the Inventory document (Medibank – LCA – Inventory.docx). This reliance on generic data may result in high uncertainty in the outcomes. Sensitivity analysis was conducted to assess the impact of key assumptions made in the study (Appendix N), and the potential influence of these assumptions on the results is discussed in the uncertainty analysis section (Appendix D). The main sources of uncertainty include the proportion of BKBM participants who undergo TKR after the program, the materials used in the BKBM welcome pack, and the travel distances of patients and medical staff, particularly in rural areas. The results showed significant differences between the virtual health and in-hospital care scenarios across most impact categories, indicating that uncertainties due to assumptions are unlikely to reverse the relative environmental performance of the scenarios. This limitation should be considered when communicating the results.

Additionally, it's important to note that this study assumed the treatment outcomes in the scenarios are comparable. In reality, a range of outcomes is expected depending on the individual participant or patient. The study's results and interpretations are based on this assumption.

Considerations

Consideration of extending the temporal system boundary:

This study compared multiple scenarios of knee pain management assuming the outcomes of the scenarios are comparable, however, it's worth noting that some BKBM participants/TKR patients may require further treatment.

Conducting an LCA over an extended timeframe enables a more comprehensive environmental impact assessment of knee pain management.

Furthermore, using detailed data from Medibank and its partners/members in the LCA enhances the accuracy of environmental impact assessment, particularly focusing on areas identified as significant contributors to impact in this study.

BKBM welcome pack

To gather comprehensive data on the environmental impacts of items in the BKBM welcome pack, consider posing targeted questions to suppliers for each product, such as:

- **Corporate policies:** What are your sustainability goals and policies?
- **Third-party certifications:** Do your products have any environmental certifications here or in any other regions?
- **Materials sourcing:** What materials or electronic components are used and how are they sourced and managed (e.g., sustainably managed forests)?
- **Material Composition:** What materials are used, what are their environmental impacts, and do they contain any hazardous materials?
- **Manufacturing process:** What is the energy consumption during manufacturing?
- **Packaging:** Are packaging materials recyclable or biodegradable?
- **Freight transport:** What transport modes are used, and how is the carbon footprint minimised?
- **Durability and lifespan:** How durable are the products, and what is their expected lifespan?
- **End-of-Life:** Is there a take-back or recycling programme for end-of-life products?

These questions will help assess the environmental impacts of each component in the welcome pack and identify areas for improvement in production and lifecycle management.

Surgical operations

Given the limitations in primary data, future collection of the following data will enable the identification of specific improvements in surgical operations, including:

- Energy consumption: Record total energy use in surgical areas, including lighting and medical equipment. Analyse peak usage and explore renewable energy options.
- Water usage: Monitor water usage in surgical procedures and related activities and review against water recycling and more efficient sterilisation systems in market.
- Waste management: Evaluate the types and volumes of waste produced, focusing on hazardous and non-hazardous waste, and review disposal and recycling methods to enhance waste reduction strategies.
- Equipment and materials used: Investigate the environmental impacts of surgical instruments and supplies throughout their lifecycle, comparing reusable and single-use items and assessing supplier sustainability practices.
- Staff training and protocols: Review staff practices and protocols impacting environmental efficiency, aiming to refine these to minimise environmental impact without compromising healthcare quality.

This focused data collection can help guide the development of targeted strategies to reduce the environmental footprint and support sustainable practices.

Appendices

Acronyms

Acronym or Term	Definition
LCA	Life Cycle Assessment
BKBM	Better Knee Better Me program
TKR	Total Knee Replacement
ISO	International Organisation for Standardisation
DALY	Disability Adjusted Life Years
USD	United States dollar(s)

Midpoint indicators

Impact category	Abbreviation	Indicator	Unit
Global warming potential	GWP	Infrared radiative forcing increase	kg CO_2 eq.
Stratospheric ozone depletion	ODP	Stratospheric ozone decrease	kg CFC11 eq.
Ionizing radiation	IRP	Ionizing radiation potential	kBq Co-60 eq.
Ozone formation, Human health	HOFP	Stratospheric ozone population intake increase	kg NO_x eq.
Fine particulate matter formation	PMFP	PM2.5 population intake	kg PM2.5 eq.
Ozone formation, Terrestrial ecosystems	EOFP	Stratospheric ozone increase	kg NO_x eq.
Terrestrial acidification	TAP	Proton increase in natural soil	kg SO_2 eq.
Freshwater eutrophication	FEP	Phosphorous increase in freshwater	kg P eq.
Marine eutrophication	MEP	Dissolved inorganic nitrogen increase in marine water	kg N eq.
Terrestrial ecotoxicity	TETP	Hazard-weighted increase in natural soils	kg 1,4-DCB
Freshwater ecotoxicity	FETP	Hazard-weighted increase in freshwater	kg 1,4-DCB
Marine ecotoxicity	METP	Hazard-weighted increase in marine water	kg 1,4-DCB
Human carcinogenic toxicity	HTPc	Risk increase of cancer disease incidence	kg 1,4-DCB
Human non-carcinogenic toxicity	HTPnc	Risk increase of non-cancer disease incidence	kg 1,4-DCB
Land use	LOP	Occupation and time-integrated land transformation	m^2a crop eq.
Mineral resource scarcity	SOP	Increase of ore extracted	kg Cu eq.
Fossil resource scarcity	FFP	Upper heating value	kg oil eq.
Water consumption	WCP	Increase of water consumed	m^3

Endpoint indicators

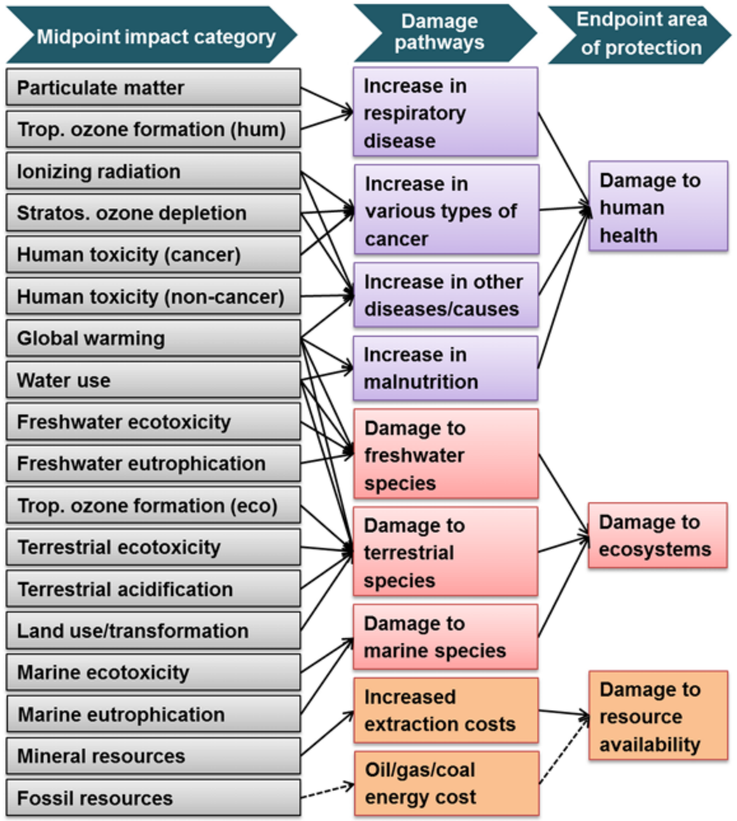
The **damage to human health** estimates the years lost to premature death and expresses the reduced quality of life due to illness. The Disability Adjusted Life Years (DALY) unit is used to quantify the burden of human disease resulting from environmental pollution and attribute it to the life cycle of the product.

In the case of **damage to ecosystem**, the Species.yr (species loss per year) unit is used to quantify the damage to ecosystems that represents the local species loss integrated over time (species year).

With regard to damage to **resource availability**, the USD2013 unit is used to quantify the increased cost due to increasing resource extraction.

Impact category	Abbreviation	Indicator	Unit
Human health	HH	Damage to human health	DALY
Ecosystems	ED	Damage to ecosystem quality	Species.yr
Resource availability	RA	Damage to resource availability	USD (2013)

Relationship between ReCiPe midpoint and endpoint indicators



List of the midpoint impact categories covered in the ReCiPe 2016 method and their relation to the areas of protection (endpoint impact categories).

Environmental impact hotspot analysis: Virtual health-BKBM – Urban - Midpoint

Highest impact — Lowest impact

		Pre-program	BKBM - telehealth	BKBM - Welcome	Home stay	Post-program care	Post-BKBM TKR
Global warming	kg CO2 eq	1.18E+00	1.66E+00	1.18E+01	8.28E+00	8.97E-02	1.67E+02
Stratospheric ozone depletion	kg CFC11 eq	2.57E-07	5.32E-07	2.94E-06	1.09E-05	2.87E-08	3.37E-05
Ionizing radiation	kBq Co-60 eq	7.34E-03	1.66E-01	5.90E-01	1.70E-01	8.95E-03	1.21E+00
Ozone formation, Human health	kg NOx eq	1.07E-03	3.83E-03	2.58E-02	1.89E-02	2.07E-04	3.90E-01
Fine particulate matter formation	kg PM2.5 eq	2.63E-04	3.22E-03	2.87E-02	1.11E-02	1.74E-04	2.14E-01
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.27E-03	3.90E-03	2.71E-02	1.92E-02	2.11E-04	3.94E-01
Terrestrial acidification	kg SO2 eq	1.28E-03	5.77E-03	3.45E-02	3.47E-02	3.12E-04	6.79E-01
Freshwater eutrophication	kg P eq	6.81E-05	7.91E-04	3.81E-03	2.72E-03	4.27E-05	1.08E-02
Marine eutrophication	kg N eq	2.99E-05	6.38E-05	7.35E-04	1.26E-02	3.45E-06	1.52E-02
Terrestrial ecotoxicity	kg 1,4-DCB	1.65E+00	3.14E+00	1.99E+02	2.64E+00	1.70E-01	1.48E+02
Freshwater ecotoxicity	kg 1,4-DCB	7.16E-03	1.32E-01	5.72E-01	7.99E-02	7.13E-03	1.79E+00
Marine ecotoxicity	kg 1,4-DCB	9.16E-03	1.75E-01	8.42E-01	6.52E-02	9.44E-03	2.34E+00
Human carcinogenic toxicity	kg 1,4-DCB	3.26E-03	5.66E-02	1.09E+01	6.03E-02	3.06E-03	2.01E+00
Human non-carcinogenic toxicity	kg 1,4-DCB	1.22E-01	2.51E+00	1.07E+01	2.26E+00	1.36E-01	2.90E+01
Land use	m2a crop eq	1.29E-03	1.68E-02	4.76E-01	1.12E+00	9.08E-04	2.40E+00
Mineral resource scarcity	kg Cu eq	3.29E-04	6.74E-03	5.92E-01	2.01E-03	3.64E-04	8.42E-01
Fossil resource scarcity	kg oil eq	3.18E-01	3.87E-01	2.92E+00	1.82E+00	2.09E-02	2.79E+01
Water consumption	m3	5.13E-03	7.89E-03	9.50E-02	1.49E+00	4.27E-04	2.10E+00

*The impacts associated with 'Home stay' are included for a duration equivalent to the post-surgery hospital stay in in-hospital care scenarios.

Environmental impact hotspot analysis: Virtual health-BKBM - Rural - Midpoint

Highest impact — Lowest impact

		Pre-program	BKBM - telehealth	BKBM - Welcome	Home stay	Post-program care	Post-BKBM TKR
Global warming	kg CO2 eq	4.29E+00	1.66E+00	1.21E+01	8.28E+00	8.97E-02	2.37E+02
Stratospheric ozone depletion	kg CFC11 eq	9.59E-07	5.32E-07	3.09E-06	1.09E-05	2.87E-08	4.96E-05
Ionizing radiation	kBq Co-60 eq	1.63E-02	1.66E-01	5.90E-01	1.70E-01	8.95E-03	1.41E+00
Ozone formation, Human health	kg NOx eq	3.30E-03	3.83E-03	2.65E-02	1.89E-02	2.07E-04	4.40E-01
Fine particulate matter formation	kg PM2.5 eq	5.06E-04	3.22E-03	2.88E-02	1.11E-02	1.74E-04	2.20E-01
Ozone formation, Terrestrial ecosystems	kg NOx eq	4.03E-03	3.90E-03	2.79E-02	1.92E-02	2.11E-04	4.56E-01
Terrestrial acidification	kg SO2 eq	3.78E-03	5.77E-03	3.50E-02	3.47E-02	3.12E-04	7.35E-01
Freshwater eutrophication	kg P eq	9.44E-05	7.91E-04	3.82E-03	2.72E-03	4.27E-05	1.14E-02
Marine eutrophication	kg N eq	8.97E-05	6.38E-05	7.41E-04	1.26E-02	3.45E-06	1.65E-02
Terrestrial ecotoxicity	kg 1,4-DCB	6.23E+00	3.14E+00	2.02E+02	2.64E+00	1.70E-01	2.53E+02
Freshwater ecotoxicity	kg 1,4-DCB	1.14E-02	1.32E-01	5.73E-01	7.99E-02	7.13E-03	1.88E+00
Marine ecotoxicity	kg 1,4-DCB	1.20E-02	1.75E-01	8.45E-01	6.52E-02	9.44E-03	2.41E+00
Human carcinogenic toxicity	kg 1,4-DCB	3.85E-03	5.66E-02	1.09E+01	6.03E-02	3.06E-03	2.02E+00
Human non-carcinogenic toxicity	kg 1,4-DCB	1.40E-01	2.51E+00	1.07E+01	2.26E+00	1.36E-01	2.95E+01
Land use	m2a crop eq	2.69E-03	1.68E-02	4.76E-01	1.12E+00	9.08E-04	2.43E+00
Mineral resource scarcity	kg Cu eq	7.14E-04	6.74E-03	5.92E-01	2.01E-03	3.64E-04	8.51E-01
Fossil resource scarcity	kg oil eq	1.09E+00	3.87E-01	3.02E+00	1.82E+00	2.09E-02	4.54E+01
Water consumption	m3	6.44E-03	7.89E-03	9.52E-02	1.49E+00	4.27E-04	2.13E+00

*The impacts associated with 'Home stay' are included for a duration equivalent to the post-surgery hospital stay in in-hospital care scenarios.

Environmental impact hotspot analysis: In-hospital care – Urban - Midpoint

Highest impact — Lowest impact

		Pre-surgery	Surgery	Rehabilitation	Post-surgery
Global warming	kg CO2 eq	1.05E+01	2.25E+02	3.04E+02	1.76E+01
Stratospheric ozone depletion	kg CFC11 eq	4.39E-06	5.62E-05	4.59E-05	6.01E-06
Ionizing radiation	kBq Co-60 eq	7.25E-02	3.67E+00	2.32E-01	6.73E-02
Ozone formation, Human health	kg NOx eq	9.99E-03	5.51E-01	7.24E-01	1.42E-02
Fine particulate matter formation	kg PM2.5 eq	3.05E-03	3.22E-01	3.85E-01	2.58E-03
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.15E-02	5.56E-01	7.28E-01	1.71E-02
Terrestrial acidification	kg SO2 eq	1.23E-02	9.81E-01	1.25E+00	1.67E-02
Freshwater eutrophication	kg P eq	5.89E-04	3.00E-02	5.05E-03	4.12E-04
Marine eutrophication	kg N eq	2.77E-03	2.13E-02	2.61E-02	3.67E-04
Terrestrial ecotoxicity	kg 1,4-DCB	1.29E+01	4.18E+02	3.77E+01	2.52E+01
Freshwater ecotoxicity	kg 1,4-DCB	7.46E-01	4.79E+00	3.85E-01	4.76E-02
Marine ecotoxicity	kg 1,4-DCB	1.05E+00	6.25E+00	4.70E-01	5.09E-02
Human carcinogenic toxicity	kg 1,4-DCB	3.28E-02	6.55E+00	1.04E-01	1.82E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	3.34E+00	8.93E+01	3.52E+00	6.22E-01
Land use	m2a crop eq	5.85E-02	6.37E+00	1.55E+00	1.26E-02
Mineral resource scarcity	kg Cu eq	2.30E-03	2.80E+00	5.08E-03	3.00E-03
Fossil resource scarcity	kg oil eq	2.56E+00	3.73E+01	4.88E+01	4.49E+00
Water consumption	m3	4.26E-02	3.23E+00	3.69E+00	2.87E-02

Environmental impact hotspot analysis: In-hospital care – Rural - Midpoint

		Pre-surgery	Surgery	Rehabilitation	Post-surgery
Global warming	kg CO2 eq	3.42E+01	2.82E+02	3.43E+02	1.30E+02
Stratospheric ozone depletion	kg CFC11 eq	9.75E-06	6.91E-05	5.49E-05	3.15E-05
Ionizing radiation	kBq Co-60 eq	1.41E-01	3.84E+00	3.46E-01	3.92E-01
Ozone formation, Human health	kg NOx eq	2.70E-02	5.92E-01	7.53E-01	9.53E-02
Fine particulate matter formation	kg PM2.5 eq	4.92E-03	3.27E-01	3.88E-01	1.14E-02
Ozone formation, Terrestrial ecosystems	kg NOx eq	3.26E-02	6.08E-01	7.63E-01	1.18E-01
Terrestrial acidification	kg SO2 eq	3.14E-02	1.03E+00	1.28E+00	1.08E-01
Freshwater eutrophication	kg P eq	7.90E-04	3.05E-02	5.39E-03	1.37E-03
Marine eutrophication	kg N eq	3.22E-03	2.23E-02	2.69E-02	2.54E-03
Terrestrial ecotoxicity	kg 1,4-DCB	4.80E+01	5.07E+02	9.62E+01	1.92E+02
Freshwater ecotoxicity	kg 1,4-DCB	7.79E-01	4.86E+00	4.39E-01	2.01E-01
Marine ecotoxicity	kg 1,4-DCB	1.07E+00	6.30E+00	5.07E-01	1.55E-01
Human carcinogenic toxicity	kg 1,4-DCB	3.73E-02	6.56E+00	1.11E-01	3.94E-02
Human non-carcinogenic toxicity	kg 1,4-DCB	3.47E+00	8.98E+01	3.74E+00	1.25E+00
Land use	m2a crop eq	6.92E-02	6.40E+00	1.56E+00	6.36E-02
Mineral resource scarcity	kg Cu eq	5.25E-03	2.80E+00	1.00E-02	1.70E-02
Fossil resource scarcity	kg oil eq	8.46E+00	5.15E+01	5.86E+01	3.26E+01
Water consumption	m3	5.27E-02	3.26E+00	3.71E+00	7.66E-02

Environmental impact hotspot analysis: Endpoint

Highest impact — Lowest impact

Telehealth - BKBM - Urban

		Pre-program exam.	BKBM - telehealth	BKBM - Welcome pack	Home stay*	Post-program care	Post-BKBM TKR
Human Health	DALY	1.39E-06	4.33E-06	6.60E-05	1.55E-05	2.34E-07	3.06E-04
Ecosystem	species.yr	3.62E-09	7.23E-09	4.95E-08	7.52E-08	3.91E-10	7.32E-07
Resource	USD2013	1.29E-01	7.76E-02	9.32E-01	5.14E-01	4.19E-03	7.95E+00

Telehealth - BKBM - Rural

		Pre-program exam.	BKBM - telehealth	BKBM - Welcome pack	Home stay*	Post-program care	Post-program care
Human Health	DALY	4.88E-06	4.33E-06	6.64E-05	1.55E-05	2.34E-07	3.85E-04
Ecosystem	species.yr	1.28E-08	7.23E-09	5.06E-08	7.52E-08	3.91E-10	9.40E-07
Resource	USD2013	4.78E-01	7.76E-02	9.72E-01	5.14E-01	4.19E-03	1.58E+01

In-hospital care - Urban

		Pre-surgery exam.	Surgery	Rehabilitation	Post-surgery care
Human Health	DALY	1.36E-05	4.59E-04	5.28E-04	2.05E-05
Ecosystem	species.yr	3.44E-08	1.03E-06	1.32E-06	5.37E-08
Resource	USD2013	1.09E+00	1.05E+01	1.29E+01	1.99E+00

In-hospital care - Rural

		Pre-surgery exam.	Surgery	Rehabilitation	Post-surgery care
Human Health	DALY	4.03E-05	5.23E-04	5.73E-04	1.48E-04
Ecosystem	species.yr	1.05E-07	1.20E-06	1.44E-06	3.89E-07
Resource	USD2013	3.75E+00	1.69E+01	1.74E+01	1.47E+01

*The impacts associated with 'Home stay' are included for a duration equivalent to the post-surgery hospital stay in in-hospital care scenarios.

LCA as sustainability tool

The rigorous, science-based approach of LCA is perfect for assessing the impact of products and services, identifying environmental impact hotspots, and undertaking comparisons with peers and alternatives. The analytical components of an LCA process are well-defined (for example, within ISO14040), and typically consist of four key stages. These are as follows:

Goal and scope: This stage defines which elements of a product's life cycle will be taken into account, key analysis parameters, and the aims of the study.

Inventory analysis: In this step, the material and energy flows within the product system are quantified and built into an LCA model.

Impact assessment: The data gathered into the inventory are assessed for its impact across a defined set of impact categories.

Interpretation: This is the critical stage, and it involves expert review of the results to uncover key insights. The interpretation may also lead to subsequent refinement of input data and the model.

LCA can be undertaken at various levels: From high-level screening LCA analysis, through to very detailed assessments. The former may involve a simpler model and greater use of standard data accessed from various LCA databases, as well as a high level of assumptions. The latter is likely to involve much greater use of primary, material-specific data.

Specification of data quality requirements - Data sources, requirements and quality assessment

To guarantee the credibility of the outcomes yielded by this LCA, it's imperative to uphold a rigorous standard for the quality of input data. The data employed must be as current and pertinent as possible. This study considers scenarios in Australia. Hence, whenever feasible, it is advisable to utilize precise regional data. As the participants and patients are across the country, an aggregated dataset has been used for processes occurring in Australia, for example, electricity, landfill, etc. Furthermore, any elements tied to technology should align with the timeframe pertinent to the product. For data obtained externally, it is essential to maintain consistency and representation, along with clear referencing of sources to facilitate reproducible results.

The data quality was quantitatively assessed, as shown in the following slides, using a scale from 1 to 5, where 1 = very good, 2 = good, 3 = fair, 4 = poor, and 5 = very poor. Since this study is a comparative assessment of different scenarios rather than an exact estimation of impacts, a data quality score between 2 and 2.5 would likely meet the required standard. The average scores for the virtual health and in-hospital care scenarios are 2.0 and 2.1, respectively, which fall within the acceptable range.

The data quality across all scenarios should be high and comparable to minimize uncertainty in the comparisons. The significant difference in resulted impacts between the virtual health and in-hospital care scenarios, along with the insignificant contributions from items with relatively low data quality, suggests that the overall data quality in this study is sufficient for the scope of this study.

Specification of data quality requirements - Data quality assessment scheme

	Description	1	2	3	4	5	Reference
time-related coverage	age of data and the minimum length of time over which data should be collected	Less than 3 years of difference to the time period of the dataset	Less than 6 years of difference of the time period of the dataset	Less than 10 years of difference to the time period of the dataset	Less than 15 years of difference to the time period of the dataset	Age of data unknown or more than 15 years of difference to the time period of the dataset	1
geographical coverage	geographical area from which data for unit processes should be collected to satisfy the goal of the study	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown or distinctly different area	1
technology coverage	specific technology or technology mix	Data from enterprises, processes and materials under study	Data from processes and materials under study (i.e. identical technology) but from different enterprises	Data from processes and materials under study from different technology	Data on related processes or materials	Data on related processes on laboratory scale or from different technology	
precision	measure of the variability of the data values for each data expressed (e.g. variance)	Measured/calculated and verified. Very low uncertainty (< 7%)	Measured/calculated/literature and plausibility checked by reviewer	Measured/calculated/literature and plausibility not checked by reviewer OR Qualified estimate based on calculations plausibility checked by reviewer	Qualified estimate based on calculations, plausibility not checked by reviewer	Rough estimate with known deficits	2
completeness	percentage of flow that is measured or estimated	>80% of determined flows have been evaluated and given a value	60-79% of determined flows have been evaluated and given a value	40-59% of determined flows have been evaluated and given a value	<40% of determined flows have been evaluated and given a value	Process completeness not scored	3
representativeness	qualitative assessment of the degree to which the data set reflects the true population of interest (i.e. geographical coverage, time period and technology coverage)	Average of technological, geographical, and time-related coverage is considered as "representativeness"					4
consistency	qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis	Scored by how far the "precison" score is from the average "precision". Within +/ - 10% of average.	Scored by how far the "precison" score is from the average "precision". Between >10% and <25% higher or lower than average.	Scored by how far the "precison" score is from the average "precision". Between >25% and <50% higher or lower than average.	Scored by how far the "precison" score is from the average "precision". Between >50% and <75% higher or lower than average.	Scored by how far the "precison" score is from the average "precision". >75% higher or lower than average.	4
reproducibility	qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study	A specific value of data used in the assessment and its source are clearly provided.	A specific value of data used in the assessment is provided. Its source is not clear.	Only a range of data values, rather than a specific value, and its source are provided.	Only a range of data values, rather than a specific value, is provided. Its source is unclear.	A value used in the assessment is not disclosed.	4
sources of the data	data source	Verified data based on measurements	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on assumptions	Qualified estimate (e.g. by industrial expert)	Non-qualified estimate	1
uncertainty of the information	uncertainty of the information (e.g. data, models and assumptions)	Sample size of n>8 as based on expert measurement and externally verified and adequate sample size	sample size 8>n>1 as based on expert measurements or verified computational models	n=1 Extert elicitation 4 step procedure; Bom, factory data calculations	n=1 Expert elicitation point-value, reasonability checked	n=1 Non-expert estimate not based on literature	5

1. Ciroth, A., Muller, S., Weidema, B. et al. Empirically based uncertainty factors for the pedigree matrix in ecoinvent. Int J Life Cycle Assess 21, 1338–1348 (2016).
2. Federal LCA Commons. "ILCD data quality system" (2018)
3. USEPA. "Guidance on Data Quality Assessment for Life Cycle Inventory Data" (2016)
4. JRC. "ILCD Handbook - General guide on LCA - Detailed guidance" (2010)
5. Bagchus, "A data quality assessment method for life cycle inventories in LCA" (2023)

Data validity check – Virtual health scenario

	time-related coverage	geographical coverage	technology coverage	precision	completeness	representativenes s	consistency	reproducibility	sources of the data	uncertainty of the information
Virtual health scenario										
Pre-program										
Cover check - phone call	2	2	2	3	2	2	3	2	3	3
Online survey - internet usage	2	2	2	3	2	2	3	2	3	3
Clinical screening - phone call	2	2	2	3	2	2	3	2	3	3
Home space use	2	2	2	2	2	2	2	1	2	2
GP visit - travel distance	2	2	-	3	2	2	3	2	3	3
GP visit - travel mode	2	2	2	2	2	2	2	2	2	2
GP visit - facility use	2	2	2	3	2	2	3	1	2	2
GP visit - consumables	2	2	2	2	2	2	2	1	1	2
GP visit - staffing	2	2	-	3	2	2	3	2	2	2
GP visit - fraction of participants who required GP visit	1	1	-	1	1	1	4	1	1	2
Care at home										
Physiotherapy - internet usage	2	2	2	2	2	2	2	1	2	2
Physiotherapy - space use	2	2	2	2	2	2	2	1	2	2
Dietary consultation - inernet usage	2	2	2	2	2	2	2	1	2	2
Dietary consultation - space use	2	2	2	2	2	2	2	1	2	2
BKBM package - items inlucded	2	2	2	2	2	2	2	2	2	2
BKBM package - delivery	2	2	2	3	2	2	3	2	3	3
BKBM package - item disposal	2	2	2	2	2	2	2	2	3	3
Post-program										
Final review - interne usage	2	2	2	2	2	2	2	1	2	2
Final review - space use	2	2	2	2	2	2	2	1	2	2
Post-BKBM TKR										
Post-BKBM TKR - fraction of participants undergo TKR	1	1	-	1	1	1	4	1	1	2

Data validity check– In-hospital care scenario

	time-related coverage	geographical coverage	technology coverage	precision	completeness	representativeness	consistency	reproducibility	sources of the data	uncertainty of the information
In-hospital care										
Pre-surgery										
Physiotherapy - travel distance	2	2	-	3	2	2	3	2	3	3
Physiotherapy - travel mode	2	2	2	2	2	2	2	2	2	2
Physiotherapy - staffing	2	2	-	3	2	2	3	2	2	2
Physiotherapy - space use	2	2	2	2	2	2	2	1	2	2
Pre-admission clinic										
Clinic visit - travel distance	2	2	-	3	2	2	3	2	3	3
Clinic visit - travel mode	2	2	2	2	2	2	2	2	2	2
Clinic visit - staffing	2	2	-	3	2	2	3	1	2	2
Clinic visit - space use	2	2	2	2	2	2	2	1	2	2
Clinic visit - consumable	2	2	2	2	2	2	2	1	1	2
Clinic visit - blood test	2	2	2	2	2	2	2	1	1	2
Clinic visit - X-ray	2	2	2	3	2	2	3	2	2	3
Clinic visit - Urine test	2	2	2	2	2	2	2	1	1	2
Surgery										
Hospital visit - travel distance	2	2	-	3	2	2	3	2	3	3
Hospital visit - travel mode	2	2	2	2	2	2	2	2	2	2
Hospital visit - staffing	2	2	-	3	2	2	3	1	2	3
Hospital visit - space use	2	2	2	2	2	2	2	1	2	2
Surgery - TKR	2	2	2	3	2	2	3	1	1	2
Surgery - anaesthesia	2	2	2	2	2	2	2	1	1	2
Surgery - X-ray	2	2	2	3	2	2	3	2	2	2
Surgery - consumables	2	2	2	3	2	2	3	1	1	2
Surgery - waste treatment	2	2	2	3	2	2	3	1	1	2
Post-surgery care										
Medication	2	2	2	2	2	2	2	2	2	2
Hospital visit - travel distance	2	2	-	3	2	2	3	2	3	3
Hospital visit - travel mode	2	2	2	2	2	2	2	2	2	2
Hospital - staffing	2	2	-	3	2	2	3	1	2	2
Hospital - space use	2	2	2	2	2	2	2	1	2	2
Rehabilitation										
Distribution across rehabilitation modes	1	1	-	1	1	1	4	1	1	2
Length of rehabilitation	2	2	2	3	2	2	3	2	2	3
Hospital visit - travel distance	2	2	-	3	2	2	3	2	3	3
Hospital visit - travel mode	2	2	2	2	2	2	2	2	2	2
Hospital visit - staffing	2	2	-	3	2	2	3	2	2	3
Hospital visit - space use	2	2	2	2	2	2	2	2	2	2
Hospital visit - visit frequency	2	2	2	3	2	2	3	2	3	3
Medical staff home visit - travel distance	2	2	-	3	2	2	3	2	3	3
Medical staff home visit - travel mode	2	2	2	2	2	2	2	2	2	2
Medical staff home visit - space use	2	2	2	2	2	2	2	1	2	2
Self management - space use	2	2	2	2	2	2	2	1	2	2

Completeness checks

Assessment phase	Completeness check
Goal and scope	The goal and scope of the study was clearly defined and the assumptions and exclusions were clearly addressed.
Inventory	All the relevant data were collected through rigorous open-source research when Medibank specific data was unavailable.
Impact assessment	All midpoint and endpoint impact categories available in the ReCiPe method were examined. The ReCiPe method has been widely accepted and applied globally.
Interpretation	The results answered the research question and identified the hotspots.

Consistency checks

Aspect	Discussion
Assumptions	The key assumptions made in the LCA include travel distances for participants, patients, and medical staff, the patient-to-staff ratio in medical facilities, the lifespan of items in the BKBM welcome pack, and the fraction of BKBM participants who undergo TKR after the program. These assumptions were consistently applied across the scenarios when applicable and are clearly presented in the "LCA Method" section. The influence of these assumptions was examined in the sensitivity analysis.
Methods	The LCA was conducted in alignment with ISO 14040/14044 standards. The functional unit and system boundaries were defined consistently across all scenarios to ensure comparability and to achieve the study's goal and scope.
Data	The data sources are presented in Appendix Q and assessed for their quality in Appendix K. The data for inputs and outputs of the systems/services involved in each scenario were primarily collected through a literature search, fulfilling the goal and scope of the LCA by enabling quantitative comparison of impacts associated with different modes of knee pain managements.

Sensitivity analysis

Sensitivity analysis was performed to examine the influence of key assumptions made in the LCA. These include:

- Travel distances of the participants, patients, and medical staff - The base case values were adjusted to half and 50% longer distance.
- Staff allocation at medical facilities - The number of patients each medical staff is responsible for per day was adjusted to half and 50% more than the base case setting.
- The fraction of the BKBM participants who undergo TKR after the program – The fraction was adjusted to 25% and 50% less than the base case fraction.
- BKBM welcome pack – The items provided were assumed to be used only within the BKBM program (1 year) in the base case setting. This was adjusted to 5 years and 10 years.

Sensitivity analysis – Midpoint results

The numerical results and the relative impacts compared to the base case for each parameter tested are provided in the following slides. Key findings are summarised below.

- Scenarios in rural settings were more affected by variations in the travel distances of participants, patients, and medical staff due to the longer travel distances. The most affected impact categories were Global Warming Potential, Stratospheric Ozone Depletion, Terrestrial Ecotoxicity, and Fossil Resource Scarcity. These impacts increased by 14%-25% in rural settings when travel distance increased by 50%, while only a 3%-7% increase was observed in urban settings. When the distance was reduced by 50%, these impacts decreased by 14%-25% in rural settings and by 3%-7% in urban settings.
- The number of patients per staff at medical facilities had minimal influence on the overall impacts across all impact categories, with the most affected being Terrestrial Ecotoxicity, which increased by up to 6% when the number of patients per staff was reduced by 50%.
- The fraction of BKBM participants who undergo TKR after the program significantly affected the overall impacts of the virtual health scenarios in both urban and rural settings. Halving this fraction reduced impacts by 21%-42%, except for Human Carcinogenic Toxicity, which only reduced by 8%. When the fraction decreased by 25%, impacts were reduced by 11%-21%, except for Human Carcinogenic Toxicity, which reduced only by 4%.
- The duration of the BKBM welcome pack's assumed utilization also showed significant influence on the overall impacts of the virtual health scenarios. For example, extending the use of the items to 5 and 10 years decreased Human Carcinogenic Toxicity by 67% and 76%, respectively. Other impacts such as Ionizing Radiation, Terrestrial Ecotoxicity, and Mineral Resource Scarcity also considerably reduced.

Sensitivity analysis – Travel distance: +50%

Table N1: Sensitivity analysis results – travel distance: +50% – numerical midpoint results

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	2.0E+02	5.0E-05	2.2E+00	4.5E-01	2.6E-01	4.5E-01	7.6E-01	1.8E-02	2.9E-02	3.7E+02	2.6E+00	3.5E+00	1.3E+01	4.5E+01	4.0E+00	1.4E+00	3.5E+01	3.7E+00
Virtual health - BKBM - Rural	3.1E+02	7.5E-05	2.5E+00	5.3E-01	2.7E-01	5.5E-01	8.5E-01	1.9E-02	3.1E-02	5.3E+02	2.7E+00	3.6E+00	1.3E+01	4.6E+01	4.1E+00	1.5E+00	6.3E+01	3.7E+00
In-hospital care - Urban	5.8E+02	1.2E-04	4.1E+00	1.3E+00	7.2E-01	1.3E+00	2.3E+00	3.6E-02	5.1E-02	5.3E+02	6.0E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	9.9E+01	7.0E+00
In-hospital care - Rural	9.3E+02	2.0E-04	5.1E+00	1.6E+00	7.4E-01	1.6E+00	2.6E+00	3.9E-02	5.8E-02	1.1E+03	6.5E+00	8.2E+00	6.8E+00	9.9E+01	8.2E+00	2.9E+00	1.9E+02	7.2E+00

Table N2: Sensitivity analysis results – travel distance: +50% – midpoint impacts relative to the base case

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
Virtual health - BKBM - Urban	104%	104%	101%	101%	100%	102%	101%	100%	101%	103%	100%	100%	100%	100%	100%	100%	106%	100%
Virtual health - BKBM - Rural	117%	115%	105%	106%	101%	108%	104%	102%	103%	114%	102%	101%	100%	101%	100%	100%	121%	101%
In-hospital care - Urban	104%	105%	102%	101%	100%	102%	101%	101%	101%	107%	101%	100%	100%	100%	100%	100%	107%	100%
In-hospital care - Rural	118%	119%	109%	107%	102%	108%	105%	103%	105%	125%	103%	102%	100%	101%	101%	101%	123%	101%

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Sensitivity analysis – Travel distance: -50%

Table N3: Sensitivity analysis results – travel distance: -50% – numerical midpoint results

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	1.8E+02	4.7E-05	2.1E+00	4.3E-01	2.6E-01	4.4E-01	7.5E-01	1.8E-02	2.8E-02	3.4E+02	2.6E+00	3.4E+00	1.3E+01	4.5E+01	4.0E+00	1.4E+00	3.1E+01	3.7E+00
Virtual health - BKBM - Rural	2.2E+02	5.5E-05	2.2E+00	4.6E-01	2.6E-01	4.7E-01	7.8E-01	1.8E-02	2.9E-02	4.0E+02	2.6E+00	3.5E+00	1.3E+01	4.5E+01	4.0E+00	1.4E+00	4.1E+01	3.7E+00
In-hospital care - Urban	5.3E+02	1.1E-04	4.0E+00	1.3E+00	7.1E-01	1.3E+00	2.2E+00	3.6E-02	5.0E-02	4.6E+02	5.9E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	8.7E+01	7.0E+00
In-hospital care - Rural	6.5E+02	1.3E-04	4.3E+00	1.4E+00	7.2E-01	1.4E+00	2.3E+00	3.7E-02	5.2E-02	6.3E+02	6.1E+00	7.9E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	1.2E+02	7.0E+00

Table N4: Sensitivity analysis results – travel distance: -50% – midpoint impacts relative to the base case

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
Virtual health - BKBM - Urban	96%	96%	99%	99%	100%	98%	99%	100%	99%	97%	100%	100%	100%	100%	100%	100%	94%	100%
Virtual health - BKBM - Rural	83%	85%	95%	94%	99%	92%	96%	98%	97%	86%	98%	99%	100%	99%	100%	100%	79%	99%
In-hospital care - Urban	96%	95%	98%	99%	100%	98%	99%	99%	99%	93%	99%	100%	100%	100%	100%	100%	93%	100%
In-hospital care - Rural	82%	81%	91%	93%	98%	92%	95%	97%	95%	75%	97%	98%	100%	99%	99%	99%	77%	99%

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Sensitivity analysis – Number of patients per staff: +50%

Table N5: Sensitivity analysis results –number of patients per staff: +50% – numerical midpoint results

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	1.9E+02	4.8E-05	2.2E+00	4.4E-01	2.6E-01	4.4E-01	7.5E-01	1.8E-02	2.9E-02	3.5E+02	2.6E+00	3.4E+00	1.3E+01	4.5E+01	4.0E+00	1.4E+00	3.3E+01	3.7E+00
Virtual health - BKBM - Rural	2.6E+02	6.4E-05	2.4E+00	4.9E-01	2.6E-01	5.1E-01	8.1E-01	1.9E-02	3.0E-02	4.6E+02	2.7E+00	3.5E+00	1.3E+01	4.5E+01	4.0E+00	1.5E+00	5.1E+01	3.7E+00
In-hospital care - Urban	5.5E+02	1.1E-04	4.0E+00	1.3E+00	7.1E-01	1.3E+00	2.3E+00	3.6E-02	5.0E-02	4.9E+02	6.0E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	9.2E+01	7.0E+00
In-hospital care - Rural	7.8E+02	1.6E-04	4.7E+00	1.5E+00	7.3E-01	1.5E+00	2.4E+00	3.8E-02	5.5E-02	8.3E+02	6.3E+00	8.0E+00	6.7E+00	9.8E+01	8.1E+00	2.8E+00	1.5E+02	7.1E+00

Table N6: Sensitivity analysis results – number of patients per staff: +50% – midpoint impacts relative to the base case

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
Virtual health - BKBM - Urban	99%	99%	100%	100%	100%	100%	100%	100%	100%	99%	100%	100%	100%	100%	100%	100%	99%	100%
Virtual health - BKBM - Rural	99%	99%	100%	99%	100%	99%	100%	100%	100%	99%	100%	100%	100%	100%	100%	100%	98%	100%
In-hospital care - Urban	99%	99%	100%	100%	100%	100%	100%	100%	100%	99%	100%	100%	100%	100%	100%	100%	99%	100%
In-hospital care - Rural	99%	98%	99%	99%	100%	99%	100%	100%	100%	98%	100%	100%	100%	100%	100%	100%	98%	100%

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Sensitivity analysis – Number of patients per staff: -50%

Table N7: Sensitivity analysis results –number of patients per staff: -50% – numerical midpoint results

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	1.9E+02	4.9E-05	2.2E+00	4.4E-01	2.6E-01	4.5E-01	7.6E-01	1.8E-02	2.9E-02	3.6E+02	2.6E+00	3.4E+00	1.3E+01	4.5E+01	4.0E+00	1.4E+00	3.4E+01	3.7E+00
Virtual health - BKBM - Rural	2.7E+02	6.8E-05	2.4E+00	5.0E-01	2.6E-01	5.2E-01	8.2E-01	1.9E-02	3.0E-02	4.8E+02	2.7E+00	3.5E+00	1.3E+01	4.5E+01	4.0E+00	1.5E+00	5.4E+01	3.7E+00
In-hospital care - Urban	5.7E+02	1.2E-04	4.1E+00	1.3E+00	7.1E-01	1.3E+00	2.3E+00	3.6E-02	5.1E-02	5.1E+02	6.0E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	9.7E+01	7.0E+00
In-hospital care - Rural	8.2E+02	1.7E-04	4.8E+00	1.5E+00	7.3E-01	1.6E+00	2.5E+00	3.8E-02	5.6E-02	8.9E+02	6.3E+00	8.1E+00	6.8E+00	9.8E+01	8.1E+00	2.8E+00	1.6E+02	7.1E+00

Table N8: Sensitivity analysis results – number of patients per staff: -50% – midpoint impacts relative to the base case

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
Virtual health - BKBM - Urban	102%	102%	101%	101%	100%	101%	100%	100%	100%	102%	100%	100%	100%	100%	100%	100%	103%	100%
Virtual health - BKBM - Rural	104%	104%	101%	102%	100%	102%	101%	100%	101%	103%	101%	100%	100%	100%	100%	100%	105%	100%
In-hospital care - Urban	102%	103%	101%	101%	100%	101%	100%	100%	101%	104%	100%	100%	100%	100%	100%	100%	104%	100%
In-hospital care - Rural	104%	105%	102%	102%	100%	102%	101%	101%	101%	106%	101%	100%	100%	100%	100%	100%	105%	100%

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Sensitivity analysis – Post-BKBM TKR fraction: -25%

Table N9: Sensitivity analysis results – Post-BKBM TKR fraction: -25% – numerical midpoint results

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	1.5E+02	4.0E-05	1.9E+00	3.4E-01	2.0E-01	3.5E-01	5.9E-01	1.6E-02	2.5E-02	3.2E+02	2.1E+00	2.9E+00	1.2E+01	3.7E+01	3.4E+00	1.2E+00	2.6E+01	3.2E+00
Virtual health - BKBM - Rural	2.0E+02	5.3E-05	2.0E+00	3.8E-01	2.1E-01	4.0E-01	6.3E-01	1.6E-02	2.6E-02	4.0E+02	2.2E+00	2.9E+00	1.3E+01	3.8E+01	3.4E+00	1.2E+00	4.0E+01	3.2E+00
In-hospital care - Urban	5.6E+02	1.1E-04	4.0E+00	1.3E+00	7.1E-01	1.3E+00	2.3E+00	3.6E-02	5.1E-02	4.9E+02	6.0E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	9.3E+01	7.0E+00
In-hospital care - Rural	7.9E+02	1.7E-04	4.7E+00	1.5E+00	7.3E-01	1.5E+00	2.5E+00	3.8E-02	5.5E-02	8.4E+02	6.3E+00	8.0E+00	6.7E+00	9.8E+01	8.1E+00	2.8E+00	1.5E+02	7.1E+00

Table N10: Sensitivity analysis results – Post-BKBM TKR fraction: -25% – midpoint impacts relative to the base case

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
Virtual health - BKBM - Urban	78%	83%	86%	78%	79%	78%	78%	85%	87%	90%	83%	83%	96%	84%	85%	85%	79%	86%
Virtual health - BKBM - Rural	78%	81%	85%	78%	79%	78%	77%	85%	86%	86%	82%	83%	96%	84%	85%	85%	78%	86%
In-hospital care - Urban	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
In-hospital care - Rural	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Sensitivity analysis – Post-BKBM TKR fraction: -50%

Table N11: Sensitivity analysis results – Post-BKBM TKR fraction: -50% – numerical midpoint results

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	1.1E+02	3.2E-05	1.5E+00	2.4E-01	1.5E-01	2.5E-01	4.2E-01	1.3E-02	2.1E-02	2.8E+02	1.7E+00	2.3E+00	1.2E+01	3.0E+01	2.8E+00	1.0E+00	1.9E+01	2.6E+00
Virtual health - BKBM - Rural	1.4E+02	4.0E-05	1.7E+00	2.7E-01	1.5E-01	2.8E-01	4.5E-01	1.3E-02	2.2E-02	3.4E+02	1.7E+00	2.3E+00	1.2E+01	3.1E+01	2.8E+00	1.0E+00	2.9E+01	2.7E+00
In-hospital care - Urban	5.6E+02	1.1E-04	4.0E+00	1.3E+00	7.1E-01	1.3E+00	2.3E+00	3.6E-02	5.1E-02	4.9E+02	6.0E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	9.3E+01	7.0E+00
In-hospital care - Rural	7.9E+02	1.7E-04	4.7E+00	1.5E+00	7.3E-01	1.5E+00	2.5E+00	3.8E-02	5.5E-02	8.4E+02	6.3E+00	8.0E+00	6.7E+00	9.8E+01	8.1E+00	2.8E+00	1.5E+02	7.1E+00

Table N12: Sensitivity analysis results – Post-BKBM TKR fraction: -50% – midpoint impacts relative to the base case

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
Virtual health - BKBM - Urban	56%	65%	72%	56%	58%	56%	55%	70%	73%	79%	65%	66%	92%	68%	70%	71%	58%	72%
Virtual health - BKBM - Rural	55%	62%	70%	55%	58%	55%	55%	70%	72%	73%	65%	66%	92%	67%	70%	71%	56%	71%
In-hospital care - Urban	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
In-hospital care - Rural	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Sensitivity analysis – BKBM welcome pack: 5 years

Table N13: Sensitivity analysis results – BKBM welcome pack: 5 years – numerical midpoint results

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	1.8E+02	4.6E-05	1.7E+00	4.2E-01	2.3E-01	4.2E-01	7.3E-01	1.5E-02	2.8E-02	2.0E+02	2.1E+00	2.8E+00	4.3E+00	3.6E+01	3.6E+00	9.7E-01	3.1E+01	3.6E+00
Virtual health - BKBM - Rural	2.5E+02	6.3E-05	1.9E+00	4.7E-01	2.4E-01	4.9E-01	7.9E-01	1.6E-02	2.9E-02	3.1E+02	2.2E+00	2.8E+00	4.3E+00	3.7E+01	3.7E+00	9.8E-01	4.9E+01	3.6E+00
In-hospital care - Urban	5.6E+02	1.1E-04	4.0E+00	1.3E+00	7.1E-01	1.3E+00	2.3E+00	3.6E-02	5.1E-02	4.9E+02	6.0E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	9.3E+01	7.0E+00
In-hospital care - Rural	7.9E+02	1.7E-04	4.7E+00	1.5E+00	7.3E-01	1.5E+00	2.5E+00	3.8E-02	5.5E-02	8.4E+02	6.3E+00	8.0E+00	6.7E+00	9.8E+01	8.1E+00	2.8E+00	1.5E+02	7.1E+00

Table N14: Sensitivity analysis results – BKBM welcome pack: 5 years – midpoint impacts relative to the base case

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
Virtual health - BKBM - Urban	95%	95%	78%	95%	91%	95%	96%	83%	98%	55%	82%	80%	33%	81%	91%	67%	93%	98%
Virtual health - BKBM - Rural	96%	96%	80%	96%	91%	96%	97%	84%	98%	65%	83%	81%	33%	81%	91%	67%	95%	98%
In-hospital care - Urban	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
In-hospital care - Rural	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Sensitivity analysis – BKBM welcome pack: 10 years

Table N15: Sensitivity analysis results – BKBM welcome pack: 10 years – numerical midpoint results

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
	kg CO2 eq	kg CFC11 eq	kBq Co-60 eq	kg NOx eq	kg PM2.5 eq	kg NOx eq	kg SO2 eq	kg P eq	kg N eq	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	kg 1,4-DCB	m2a crop eq	kg Cu eq	kg oil eq	m3
Virtual health - BKBM - Urban	1.8E+02	4.6E-05	1.6E+00	4.2E-01	2.3E-01	4.2E-01	7.2E-01	1.5E-02	2.8E-02	1.8E+02	2.1E+00	2.7E+00	3.2E+00	3.5E+01	3.6E+00	9.1E-01	3.1E+01	3.6E+00
Virtual health - BKBM - Rural	2.5E+02	6.2E-05	1.8E+00	4.7E-01	2.4E-01	4.9E-01	7.8E-01	1.5E-02	2.9E-02	2.9E+02	2.2E+00	2.8E+00	3.2E+00	3.6E+01	3.6E+00	9.2E-01	4.9E+01	3.6E+00
In-hospital care - Urban	5.6E+02	1.1E-04	4.0E+00	1.3E+00	7.1E-01	1.3E+00	2.3E+00	3.6E-02	5.1E-02	4.9E+02	6.0E+00	7.8E+00	6.7E+00	9.7E+01	8.0E+00	2.8E+00	9.3E+01	7.0E+00
In-hospital care - Rural	7.9E+02	1.7E-04	4.7E+00	1.5E+00	7.3E-01	1.5E+00	2.5E+00	3.8E-02	5.5E-02	8.4E+02	6.3E+00	8.0E+00	6.7E+00	9.8E+01	8.1E+00	2.8E+00	1.5E+02	7.1E+00

Table N16: Sensitivity analysis results – BKBM welcome pack: 10 years – midpoint impacts relative to the base case

	GWP	ODP	IRP	HOFP	PMFP	EOFP	TAP	FEP	MEP	TETP	FETP	METP	HTPc	HTPnc	LOP	SOP	FFP	WCP
Virtual health - BKBM - Urban	94%	95%	75%	95%	90%	95%	96%	81%	98%	50%	80%	78%	25%	79%	89%	63%	92%	98%
Virtual health - BKBM - Rural	96%	96%	78%	95%	90%	95%	96%	82%	98%	61%	81%	78%	25%	79%	89%	63%	95%	98%
In-hospital care - Urban	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
In-hospital care - Rural	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

GWP: Global warming, ODP: Stratospheric ozone depletion, IRP: Ionizing radiation, HOFP: Ozone formation, Human health, PMFP: Fine particulate matter formation, EOFP: Ozone formation, Terrestrial ecosystems, TAP: Terrestrial acidification, FEP: Freshwater eutrophication, MEP: Marine eutrophication, TETP: Terrestrial ecotoxicity, FETP: Freshwater ecotoxicity, METP: Marine ecotoxicity, HTPc: Human carcinogenic toxicity, HTPnc: Human non carcinogenic toxicity, LOP: Land use, SOP: Mineral resource scarcity, FFP: Fossil resource scarcity, WCP: Water consumption

Sensitivity analysis – Endpoint results

HH: Damage to human health, ED: Damage to ecosystems, RA: Damage to resource availability

The numerical results and the relative impacts compared to the base case for each parameter tested are provided in the following slides. Key findings are summarised below.

- Scenarios in rural settings were more affected by variations in the travel distances of participants, patients, and medical staff due to the longer travel distances. The most affected categories was Damage to resource availability, increased by 25%-30% in the rural settings when the travel distance is increased by 50%.
- The number of patients per staff at medical facilities had minimal influence on the overall impacts across all impact categories, with the most affected being Damage to resource availability, which increased by up to 6% when the number of patients per staff was reduced by 50%.
- The fraction of BKBM participants who undergo TKR after the program significantly affected the overall impacts of the virtual health scenarios in both urban and rural settings. Halving this fraction reduced impacts by 41%-36%. When the fraction decreased by 25%, impacts were reduced by 18%-20%.
- The assumed utilization duration of the BKBM welcome pack most significantly influenced the Damage to Human Health category. Extending the use of the items to 5 and 10 years decreased this impact by 10%-14%. While other impact categories were also affected, the reduction was limited to between 4%-7%.

Sensitivity analysis – Travel distance

Table N17: Sensitivity analysis results – travel distance– numerical endpoint results

	Travel distance: +50%			Travel distance: -50%		
	HH	EQ	RA	HH	EQ	RA
	DALY	species.yr	USD2013	DALY	species.yr	USD2013
Virtual health - BKBM - Urban	4.0E-04	8.9E-07	1.1E+01	3.8E-04	8.4E-07	8.7E+00
Virtual health - BKBM - Rural	5.3E-04	1.2E-06	2.3E+01	4.3E-04	9.5E-07	1.3E+01
In-hospital care - Urban	1.0E-03	2.5E-06	2.9E+01	9.9E-04	2.4E-06	2.4E+01
In-hospital care - Rural	1.4E-03	3.6E-06	6.9E+01	1.1E-03	2.7E-06	3.7E+01

Table N18: Sensitivity analysis results – travel distance: +50% – endpoint impacts relative to the base case

	Travel distance: +50%			Travel distance: -50%		
	HH	EQ	RA	HH	EQ	RA
Virtual health - BKBM - Urban	102%	103%	109%	98%	97%	91%
Virtual health - BKBM - Rural	111%	112%	128%	89%	88%	72%
In-hospital care - Urban	103%	103%	111%	97%	97%	89%
In-hospital care - Rural	112%	113%	130%	88%	87%	70%

HH: Damage to human health, ED: Damage to ecosystems, RA: Damage to resource availability

Sensitivity analysis – Number of patients per staff

Table N19: Sensitivity analysis results – number of patients per staff – numerical endpoint results

	Number of patients per staff: +50%			Number of patients per staff: -50%		
	HH	EQ	RA	HH	EQ	RA
	DALY	species.yr	USD2013	DALY	species.yr	USD2013
Virtual health - BKBM - Urban	3.9E-04	8.6E-07	9.4E+00	4.0E-04	8.8E-07	1.0E+01
Virtual health - BKBM - Rural	4.7E-04	1.1E-06	1.7E+01	4.9E-04	1.1E-06	1.9E+01
In-hospital care - Urban	1.0E-03	2.4E-06	2.6E+01	1.0E-03	2.5E-06	2.8E+01
In-hospital care - Rural	1.3E-03	3.1E-06	5.1E+01	1.3E-03	3.2E-06	5.6E+01

Table N20: Sensitivity analysis results – number of patients per staff – endpoint impacts relative to the base case

	Number of patients per staff: +50%			Number of patients per staff: -50%		
	HH	EQ	RA	HH	EQ	RA
Virtual health - BKBM - Urban	100%	100%	98%	101%	101%	105%
Virtual health - BKBM - Rural	99%	99%	98%	103%	103%	107%
In-hospital care - Urban	100%	99%	98%	101%	102%	106%
In-hospital care - Rural	99%	99%	98%	103%	103%	107%

HH: Damage to human health, ED: Damage to ecosystems, RA: Damage to resource availability

Sensitivity analysis – Post-BKBM TKR fraction

Table N21: Sensitivity analysis results – Post-BKBM TKR fraction– numerical endpoint results

	Post-BKBM TKR fraction: -25%			Post-BKBM TKR fraction: -50%		
	HH	EQ	RA	HH	EQ	RA
	DALY	species.yr	USD2013	DALY	species.yr	USD2013
Virtual health - BKBM - Urban	3.2E-04	6.9E-07	7.6E+00	2.4E-04	5.0E-07	5.6E+00
Virtual health - BKBM - Rural	3.8E-04	8.5E-07	1.4E+01	2.8E-04	6.2E-07	1.0E+01
In-hospital care - Urban	1.0E-03	2.4E-06	2.7E+01	1.0E-03	2.4E-06	2.7E+01
In-hospital care - Rural	1.3E-03	3.1E-06	5.3E+01	1.3E-03	3.1E-06	5.3E+01

Table N22: Sensitivity analysis results – Post-BKBM TKR fraction – endpoint impacts relative to the base case

	Post-BKBM TKR fraction: -25%			Post-BKBM TKR fraction: -50%		
	HH	EQ	RA	HH	EQ	RA
Virtual health - BKBM - Urban	81%	79%	79%	61%	58%	59%
Virtual health - BKBM - Rural	80%	78%	78%	60%	57%	56%
In-hospital care - Urban	100%	100%	100%	100%	100%	100%
In-hospital care - Rural	100%	100%	100%	100%	100%	100%

HH: Damage to human health, ED: Damage to ecosystems, RA: Damage to resource availability

Sensitivity analysis – BKBM welcome pack

Table N23: Sensitivity analysis results – BKBM welcome pack – numerical endpoint results

	BKBM welcome pack: 5 years			BKBM welcome pack: 10 years		
	HH	EQ	RA	HH	EQ	RA
	DALY	species.yr	USD2013	DALY	species.yr	USD2013
Virtual health - BKBM - Urban	3.4E-04	8.3E-07	8.9E+00	3.3E-04	8.2E-07	8.8E+00
Virtual health - BKBM - Rural	4.2E-04	1.0E-06	1.7E+01	4.2E-04	1.0E-06	1.7E+01
In-hospital care - Urban	1.0E-03	2.4E-06	2.7E+01	1.0E-03	2.4E-06	2.7E+01
In-hospital care - Rural	1.3E-03	3.1E-06	5.3E+01	1.3E-03	3.1E-06	5.3E+01

Table N24: Sensitivity analysis results – BKBM welcome pack– endpoint impacts relative to the base case

	BKBM welcome pack: 5 years			BKBM welcome pack: 10 years		
	HH	EQ	RA	HH	EQ	RA
Virtual health - BKBM - Urban	87%	95%	92%	85%	95%	91%
Virtual health - BKBM - Rural	89%	96%	96%	87%	96%	95%
In-hospital care - Urban	100%	100%	100%	100%	100%	100%
In-hospital care - Rural	100%	100%	100%	100%	100%	100%

HH: Damage to human health, ED: Damage to ecosystems, RA: Damage to resource availability

Uncertainty analysis

The most important of the assumptions and limitations adopted in the inventory are listed in the table below. The influence of the key assumptions to the impact assessment were examined in the sensitivity analysis section.

Table O1: Uncertainty analysis

Assumption or limitation	Discussion
Raw material data	Generic processes have been used in the modelling of raw materials, involved in the BKBM welcome pack, PPE and other consumables consumed at medical facilities. The level of uncertainty of the overall results caused by this is likely low as the contributions of these materials were small except for human toxicity impacts caused by disposal of the BKBM welcome pack. Depending on the actual material used for the BKBM welcome pack, the human toxicity of the virtual health scenarios may be greatly reduced.
Transport	Transport distance of participants, patients and medical staff were the distinguishing factor between the urban and rural settings. As the transport data specific to Medibank members were not available, arbitrary numbers were used to estimate the impacts. However, the uncertainty of the overall results caused by this is limited and would not affect the conclusions regarding the impacts of each scenario relative to the others.
Staffing at medical facilities	Average of three member staff per four patients per four hours were assumed following Bartlett and Keir (2022), however, the staffing allocation may vary depending on facilities. This assumptions is unlikely to affect overall conclusions of this study due to the limited impacts caused by the medical staffs.
Post-BKBM TKR	The probability of the BKBM participants who undergo TKR after the program was unknown. Since the impacts of TKR and associated pre- and post- care are high, the fraction assumed likely affect the overall impacts of the virtual health scenarios.
BKBM welcompack	Items provided as part of BKBM welcompack was assumed to be used only for the program while some participants may use the item after the program. This would cause uncertainty to the overall results especially for the impact categories where the contributions of the BKBM welcomepack is high, such as terrestrial ecotoxicity and human carcinogenic toxicity to the extent that the conclusions around these categories may be affected.
BKBM meal replacement	Due to insufficient information on the BKBM meal replacement and the considerable variation in meals replaced depending on individuals, the impacts of the meal replacement were not included in this LCA. The influence of this exclusion on the total impacts is expected to be limited, assuming participants/patients prepare and consume meals regardless of their participation in the program.

Data sources

Primary data:

The table below provides the data sources referenced in this LCA study. Complete citations are available in Appendix K. Please refer to "Medibank - LCA - Inventory.pdf" for the inventory data used for the LCA calculations.

Items	Reference
Virtual consultations	(Bartlett et al. 2022)
Energy consumption - residential houses	(Frontier economics 2020)
Water consumption - residential houses	(ABS 2022)
Housing type	(ABS 2022)
Energy consumption - hospital	(MacNeill et al. 2017)
Water consumption - hospital	(Garcia-Sanz-Calcedo et al. 2015)
Material consumption - hospital	(Thiel et al. 2015)
Surgery - Total knee replacement	(Delaie et al. 2023), (Stall et al 2013), (Thiel et al. 2015), (MacNeill et al. 2017)
Surgery - Anaesthesia	(MacGain et al. 2021)
Presurgery examination - urine test	(McAlister et al. 2021)
Presurgery examination - blood test	(McAlister et al. 2021)
Pre/post-surgery examination - X-ray	(McAlister et al. 2022)
Drugs	(Parvatker et al. 2019)

Statistical data, including BKBM participants who undergo physical and online pre-surgery GP consultations, those who undergo total knee replacement surgery after the program, and the distribution of TKR patients across different modes of rehabilitation, were provided by Medibank.

Background data:

LCA software, SimaPro (v9.4.0.1), was used for the calculation, using AusLCI (version 1.42) and ecoinvent (version 3.9.1) as the source for background generic data.

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