ADDENDUM 7

ETHICS APPROVALS AND APPLICATIONS 2014

Author
Jako Albert Nice
jnice@csir.co.za
27240755

April 2018

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Reference number: EBIT/47/2015

09 June 2015

Mr JA Nice
Post Net Suite 112
Box 19
Menlo park
0102

Dear Mr Nice,

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Ethics Committee refers.

1 I hereby wish to inform you that the research project titled "Architecture, at a microbial nexus in Healthcare Acquired Infection; A framework for an Architectural Design Microbial Risk Model (ADMRM)" has been approved by the Committee.

This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Codes of Research Ethics of the University of Pretoria, if action is taken beyond the approved proposal.

2 According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of any member of the Faculty Committee who will deal with the matter.

3 The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof JJ Hanekom
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

UNIVERSITY OF PRETORIA

FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

APPLICATION FOR APPROVAL OF A RESEARCH PROJECT

This application form must be read with the Regulations for Research Ethics and Integrity and completed. Important: Each item must be completed.

Date of submission	08 May 2015
1. DETAILS OF APPLICANT	
1.1 Applicant's surname	Nice
1.2 Applicant's initials	JA
1.3 Applicant's title (prof, dr, mr, ms, other)	Mr.
1.4 Postal address (where approval is to be sent)	Post net suite 112, box x19, Menlo Park, 0102
1.5 E-mail address	jnice@csir.co.za
1.6 Telephone	0736629547
1.7 School in Faculty (Engineering, Built Environment or Information Technology)	Built Environment
1.8 Department	Department of Architecture
1.9 Study leader/promotor (if the applicant is a student) name, address, e-mail address	Prof. Piet Vosloo Associate Professor, Department of Architecture Building Science, Room 2-16, University of Pretoria Email: piet.vosloo@up.ac.za
1.10 Names, addresses, e-mail addresses and capacity of co-researchers/ students/ lecturers involved with the project	Co-researchers: Co-researcher - Sonya Milonova, Pretoria/Boston, sonya.milonova@gmail.com (technical advisor) Co-researcher - Gingi Khoza, Pretoria, GKhoza@csir.co.za (student) Co-researcher - Tobias van Reenen, Pretoria, TvReenen@csir.co.za (technical advisor) Co-researcher - Kevin Bingham, Durban, kbingham@gmail.com (technical advisor)
2. RESEARCH PROJECT DETAILS	
2.1 Title of research project	Architecture, at a microbial nexus in Healthcare Acquired Infection; *A framework for an Architectural Design Microbial Risk Model (ADMRM)*

2.2 Furnish as brief outline the following so that the relevant ethical aspects can be identified clearly:

- Statement of the problem
- Statement of objectives
- Experimental methods/ measuring instruments
- Materials/Apparatus
- Profile of research subjects/target group/animals/environmental factors

See attached the relevant study experiments in PDF format, briefly detailing each experiment with the noted and requested aspect listed above.

1. PhD Environmental assessment experiment proposal protocol_JN 2015
2. PhD Microbial assessment experiment proposal protocol_JN 2015
3. PhD Observational assessment experiment proposal_JN 2015

PhD research proposal abridge version Ethics_Jako Nice 08_05_2015_

Further note: This research will be conducted simultaneously with another research project: Building airborne risk estimation - Occupant population re-breathed air fraction, in which the researcher is involved with and in association with UCT, DoH WC, and the same hospitals. That research project has been approved by all parties (Department of Health WC, UCT and both hospitals) see the attached document for your information. The intention is to link this research study with that project. Once ethic approval have been awarded for this study, a resubmission will be done for the other study to all the departments concerned (Department of Health WC, UCT and both hospitals) for a combined approval from all parties.

2.3 Is a research questionnaire/ survey/interview used? (Yes or No)	Yes
2.4 If yes, have you submitted this with your application? (Yes, No or Not Applicable)	Yes

3. RESEARCH SUBJECTS

If the project involves people, either individually or in groups, complete this section

3.1 Does the study involve people as informants, or does it involve people as research subjects? (Tick one)	Informants	Yes	Research subjects	No

3.2 Describe possible safety and health implications that participation in project may pose

There are no safety concerns, other than being present in a hospital health care environment such as any other public person. If required participants will have the option to wear N95 respirators to reduce the risk of contracting nosocomial disease as an when require per standard hospital protocol.

3.3 Expected duration of participation of subjects in the project	Total to maximum of consecutive four days in summer season and four days in winter season

3.4 Describe the manner in which confidential information will be handled and confidentiality assured

No manner of personal identification of interview participant will be collected. The period of sampling will run over various working shifts thus reduce possible risk of identification. The collected data (not questionnaire) does not refer to individuals but only number of people in an environment, and environmental conditions of that environment.
The identity of the hospitals if so required by the WC Department of health will not be disclosed unless otherwise stated.

3.5 Remuneration offered to subjects for participation	No remuneration will be provided to Hospital staff, remuneration will be provided to technicians/co researchers in assisting with data logging and administration

If the project involves animals, complete this section

3.6 Describe possible safety and health implications participation in the project may hold

3.7 Expected duration of participation by animals in the project	
3.8 Care/housing/feeding of the animals during the project	

4. ENVIRONMENTAL IMPACT

If the project may have a potentially detrimental environmental impact, complete the following

4.1 Potential impact on the environment	No impact, only static monitoring of CO2, temperature and humidity
4.2 Expected duration of the impact	
4.3 Locality of the project	Western Cape, Cape Flats – Mitchells plain hospital and Khyalitsha Hospital
4.4 Preventive measures	None required

5. DISSEMINATION OF DATA

Method of publishing/application of the results	For PhD thesis and journal paper publication as part of PhD requirements

6. SUBMISSION CHECKLIST

6.1 Have you submitted the Declaration by the Researcher? (See the website for this form)	Yes
6.2 Have you submitted an example of the informed consent form to be completed by each participant? (See the website for an example)	Yes

Built Environment
PO Box 395 Pretoria 0001 South Africa
Tel: +27 12 841 4985
Fax: +27 12 841 3539

khayelitsha Hospital
Corner Steve Biko and Walter Sisulu Drives,
Cape Town, 7784
Pretoria

Attention: **Office of the CEO**

INVITATION TO PARTICIPATE IN RESEARCH

An indoor microbial and environmental investigation to determine the extent to which occupancy patterns and space use in an urban South African hospital impact users.

khayelitsha Hospital (hereafter referred to as *the hospital*) is invited to participate in a research study conducted by Jako Nice (MArch) from the Built Environment Unit at *the CSIR*. The results of the study will be contributed to a Doctoral thesis under the University of Pretoria, Department of Architecture.

This hospital was selected as a possible participant in this study because it is an urban hospital in South Africa that received matching briefs to Mithcell plain hospital but had distinctly different architectural design outcome and thus fits the case study profile.

1. PURPOSE OF THE STUDY

The purpose of the study is to determine the relationship to sampled microbiota and identification of certain organism in this hospital and the user flow and occupancy patterns as they relate to the architectural design layouts. Your

hospital was issued the same brief as another hospital but the architectural design of each varies considerably.

The outcome will contribute towards the development of a microbial design guide for architects and built environment specialist to improve the potential infection risk by HAI for both retrofit and new hospitals in building design.

2. PROCEDURES

If *the hospital* volunteers to participate in this study, we would ask the following of you:

1. Permission to mount data loggers that will collect temperature, humidity and CO2 in the room. And your permission to place an air sampler that will suck air onto a filter and collect organism and dust from the air twice a day for a maximum of 30 minutes at a time, and plates on surfaces twice a day for a total of 30 minutes each time.

   The data logger device is about the size of a cell phone and will record for 96 hour period in two seasons. This device cannot make audio recordings so no confidential conversation can be recorded. The plates are small circular Petri dishes with agar in, and the air sampler is an mechanical machine placed in the center of a room for a short time to collect Bioaerosol particles.

2. Permission for a research investigator to be present during the day from 06:00 – 18:00 in the department as unobtrusive as possible, doing hourly rounds on a fixed route: observing people using the room and counting the number of staff, patients and visitors in each room on the path.

   The purpose of the investigation is define how your department is used and how many people occupy the department over various times in the day. This person will be respectful of your right to dignity and privacy and will undertake to remain as unobtrusive as possible and will not engage with you, except to administer the questionnaire.

3. Permission for a short questionnaire to be administered regarding your perception of environment for. The investigator will issue and collect the questionnaire and be available to explain it to you if necessary. This will be have three sections as follows:

   Section A your perceptions on the infection control risk in your environment

   Section B and **Section C** is about your work schedule and the number of people in your environment.

Participants will be presented with a letter of consent to allow the above three research techniques to be implemented. They are under no obligation to give consent.

3. POTENTIAL RISKS AND DISCOMFORTS

There is potential that the presence of the research investigator may cause you to feel uncomfortable. However, the investigator is under instruction to avoid engaging with you and is to remain quiet and out of the way of normal hospital activity. The only time that the investigator is to engage with you will be to administer the questionnaire twice a day.

A number of investigators, named above, will take turns to change batteries of equipment, check recorded levels, place and collect microbial samples and take notes on an hourly walk through route that will remain the same route throughout the study, there may be a slight disturbance hourly as they make their walk through and once.

The investigator may be requested to leave the ward room for a period if sensitive activities or procedures are taking place.

The investigators will be issued with respirators by the CSIR to protect them from acquiring air-borne infections while in the hospital ward if it is deemed necessary. This can be determined by an infection risk assessment performed by the CSIR.

4. POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

You, the participant, will not benefit directly or immediately from this investigation.

The potential benefit to science is to gain a better understanding of the microbial communities that exist in the South African indoor environment and the role architecture and programming plays in order to improve hospital environments in the future, to the benefit of both patients and staff.

5. PAYMENT FOR PARTICIPATION

Neither *the hospital* nor the participants will receive payment for participation.

6. CONFIDENTIALITY

No confidential information is required for this study.

If any confidential information is accidentally obtained (over-heard by the investigator) it will not be recorded or reflected in the study and will remain confidential.

The data collected will be captured and stored electronically in a password protected domain that will only be accessible to the principle investigator.

The data collected from this study will be released to the University of Pretoria Statistics Department for statistical analysis.

The findings of this study will be published in both the doctoral thesis and scientific journals, however, the hospital and participants will not be disclosed in any publication.

7. PARTICIPATION AND WITHDRAWAL

The hospital is not obliged to participate in this study. If *the hospital* agrees to allow this study to be carried out in its facility, *the hospital* may withdraw at any time without consequences of any kind. *The hospital* may also refuse to answer any questions that it does not want to answer and still remain in the study. The investigator may withdraw *the hospital* from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact:

Principal Investigator:	Jako Nice – 0736629547, jnice@csir.co.za
Supervisor:	Prof Piet Vosloo – 012 420 4128, piet.vosloo@up.ac.za
Co-investigators:	Tobias van Reenen – TvReenen@csir.co.za
	Gingi Khoza – Gkhoza@csir.co.za
	Sonya Milonova - sonya.milonova@gmail.com
	Kevin Bingham - kbingham@gmail.com

RIGHTS OF RESEARCH SUBJECTS

The hospital may withdraw consent at any time and discontinue participation without penalty. *The hospital* is not waiving any legal claims, rights or remedies because of its participation in this research study. If *the hospital* has questions regarding its rights as a research subject, contact Dr Sandile Ncanana, the CSIR REC Secretariat, [R&DEthics@csir.co.za/012 841 4060] at the Research and Development Office.

Signature of research participant or representative in cases where a participant is uncomfortable with writing

The information above was described to me, a legal representative of *the hospital*, by Jako Nice in English and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I, on behalf of *the hospital*, hereby consent voluntarily to participate in this study and I have been given a copy of this form.

I declare that I am legally allowed to act, make decisions and grant consent on behalf of *the hospital*.

_____

Name of Participant (*the hospital*)

_____	_____	_____
Name of Representative	**Date**	**Signature**

Signature of investigator/interviewer

I, Jako Nice, declare that I explained the information given in this document to _____ [*name of the representative]* of _____ [*name of the hospital]. [H*e/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in English. There was no need for a translator since the participant understood the language used.

_____	_____
Signature of Investigator/Interviewer	**Date**

Built Environment
PO Box 395 Pretoria 0001 South Africa
Tel: +27 12 841 4985
Fax: +27 12 841 3539

Mitchells Plain Hospital
A Z Berman Drive, 8 A Z Berman Drive, Lentegeur,
Cape Town, 7786
Pretoria

Attention: **Office of the CEO**

INVITATION TO PARTICIPATE IN RESEARCH

An indoor microbial and environmental investigation to determine the extent to which occupancy patterns and space use in an urban South African hospital impact users.

Mitchells Plain Hospital (hereafter referred to as *the hospital*) is invited to participate in a research study conducted by Jako Nice (MArch) from the Built Environment Unit at *the CSIR*. The results of the study will be contributed to a Doctoral thesis under the University of Pretoria, Department of Architecture.

This hospital was selected as a possible participant in this study because it is an urban hospital in South Africa that received matching briefs to Khayelitsha hospital but had distinctly different architectural design outcome and thus fits the case study profile.

1. PURPOSE OF THE STUDY

The purpose of the study is to determine the relationship to sampled microbiota and identification of certain organism in this hospital and the user flow and occupancy patterns as they relate to the architectural design layouts. Your

hospital was issued the same brief as another hospital but the architectural design of each varies considerably.

The outcome will contribute towards the development of a microbial design guide for architects and built environment specialist to improve the potential infection risk by HAI for both retrofit and new hospitals in building design.

2. PROCEDURES

If *the hospital* volunteers to participate in this study, we would ask the following of you:

1. Permission to mount data loggers that will collect temperature, humidity and CO2 in the room. And your permission to place an air sampler that will suck air onto a filter and collect organism and dust from the air twice a day for a maximum of 30 minutes at a time, and plates on surfaces twice a day for a total of 30 minutes each time.

   The data logger device is about the size of a cell phone and will record for 96 hour period in two seasons. This device cannot make audio recordings so no confidential conversation can be recorded. The plates are small circular Petri dishes with agar in, and the air sampler is an mechanical machine placed in the center of a room for a short time to collect Bioaerosol particles.

2. Permission for a research investigator to be present during the day from 06:00 – 18:00 in the department as unobtrusive as possible, doing hourly rounds on a fixed route: observing people using the room and counting the number of staff, patients and visitors in each room on the path.

   The purpose of the investigation is define how your department is used and how many people occupy the department over various times in the day. This person will be respectful of your right to dignity and privacy and will undertake to remain as unobtrusive as possible and will not engage with you, except to administer the questionnaire.

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Participants will be presented with a letter of consent to allow the above three research techniques to be implemented. They are under no obligation to give consent.

3. POTENTIAL RISKS AND DISCOMFORTS

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4. POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

You, the participant, will not benefit directly or immediately from this investigation.

The potential benefit to science is to gain a better understanding of the microbial communities that exist in the South African indoor environment and the role architecture and programming plays in order to improve hospital environments in the future, to the benefit of both patients and staff.

5. PAYMENT FOR PARTICIPATION

Neither *the hospital* nor the participants will receive payment for participation.

6. CONFIDENTIALITY

No confidential information is required for this study.

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The data collected from this study will be released to the University of Pretoria Statistics Department for statistical analysis.

The findings of this study will be published in both the doctoral thesis and scientific journals, however, the hospital and participants will not be disclosed in any publication.

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Co-investigators:	Tobias van Reenen – TvReenen@csir.co.za
	Gingi Khoza – Gkhoza@csir.co.za
	Sonya Milonova - sonya.milonova@gmail.com
	Kevin Bingham - kbingham@gmail.com

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I, on behalf of *the hospital*, hereby consent voluntarily to participate in this study and I have been given a copy of this form.

I declare that I am legally allowed to act, make decisions and grant consent on behalf of *the hospital*.

_____

Name of Participant (*the hospital*)

_____	_____	_____
Name of Representative	**Date**	**Signature**

Signature of investigator/interviewer

I, Jako Nice, declare that I explained the information given in this document to _____ [*name of the representative]* of _____ [*name of the hospital]. [H*e/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in English. There was no need for a translator since the participant understood the language used.

_____	_____
Signature of Investigator/Interviewer	**Date**

Form FHS007: Amendment – study staff

HREC office use only (FWA00001637; IRB00001938)			
☐ Approved			
This serves as notification that all changes to the study staff and documentation described below are approved.			
Chairperson of the HREC signature		Date	

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	15 July 2015		
HREC REF Number	239/2015		
Protocol title	Building airborne risk estimation – Occupant population re-breathed air fraction.		
Protocol number (if applicable)	N/A		
Principal Investigator	Dr. Carl Morrow		
Department / Office Internal Mail Address	Desmond Tutu HIV Center, N1,21, Wernher Beit North Building, Faculty of Health Sciences		
1.1 Does this protocol receive US Federal funding?		■ Yes	☐ No

2. Items for approval

Please list on the page below all staff changes and additional documentation such as CVs and revised consent forms which need approval. This information must correspond to all 'yes' answers below. This page will be detached, signed and returned to the PI as notification of approval. Please add extra pages if necessary.

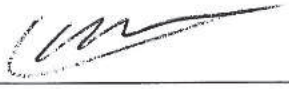
3. List of documentation (eg: CVs, Declarations & GCP Certificates)

1. Cover Letter
2. University of Pretoria Faculty Committee for Research Ethics and Integrity Approval Letter
3. Hospital Consent Form
4. Hospital Invitation (A) Khayalitsha, (B) Mitchells Plain
5. PhD proposal
6. Researcher Declaration

4. Staff changes (tick ✓)

Are new personnel being added to this research?	■ Yes	☐ No
Are current personnel being removed from this research?	☐ Yes	■ No
Is the principal investigator for this research being changed? If yes, please attach revised conflict of interest and PI declaration statements. (Refer: sections 7 and 8.4 in the New Protocol Application Form)	☐ Yes	■ No
Do the consent and assent forms need modification to reflect these staff changes? If yes, please attach copies of the revised forms, with all changes highlighted or tracked.	☐ Yes	■ No

5. Signature

My signature certifies that I will maintain the anonymity and/ or confidentiality of information collected in this research. If at any time I want to share or re-use the information for purposes other than those disclosed in the original approval, I will seek further approval from the HREC.			
Signature of PI		Date	15 July 2015

Desmond Tutu HIV Centre
Masibambane Ngezandla

DESMOND TUTU HIV CENTRE

Institute of Infectious Disease & Molecular Medicine
University of Cape Town
Faculty of Health Sciences

P O BOX 13801, MOWBRAY, 7705
Anzio Road, Observatory,
Cape Town, South Africa
(T) 27 021 650 6966 (F) 27 021 6506963

15 July 2015

HREC REF Number: 239/2015
Dear Prof Blockman

Building Airborne Risk Estimation – Occupant Population Re-Breathed Air Fraction:

Change in Staff Member, Jaco Nice

When this study protocol was initially submitted Mr Nice was listed as a co-investigator but now his application for PhD research has been approved by the University of Pretoria (UP) and I am requesting that his status changes.

Mr Nice is registered for a PhD in Architecture at the Department of Architecture, Faculty of Engineering, Built Environment & IT at UP. He is also a CSIR researcher and Fogarty Fellow.

Approval for his work has been granted by UP ethics board and the relevant proof is attached to this submission. The project includes a microbial investigation of the indoor environment, with observational analysis and static environmental data collection. A more detailed description of the study is also attached. It is the intention of the study to utilise my study design to structure Mr. Nice's investigations but I will not have any direct involvement in the project.

I hope that this is in order

Sincerely

Carl Morrow

(2)

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Reference number: EBIT/47/2015

09 June 2015

Mr JA Nice
Post Net Suite 112
Box 19
Menlo park
0102

Dear Mr Nice,

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Ethics Committee refers.

1 I hereby wish to inform you that the research project titled "Architecture, at a microbial nexus in Healthcare Acquired Infection; A framework for an Architectural Design Microbial Risk Model (ADMRM)" has been approved by the Committee.

This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Codes of Research Ethics of the University of Pretoria, if action is taken beyond the approved proposal.

2 According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of any member of the Faculty Committee who will deal with the matter.

3 The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof JJ Hanekom
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

(3)

CSIR
our future through science

Built Environment
PO Box 395
Pretoria 0001
South Africa
Tel: +27 12 841 4985
Fax: +27 12 841 3539
Email: Nmatyila@csir.co.za

CONSENT FORM TO PARTICIPATE IN RESEARCH

An indoor microbial and environmental investigation to determine the extent to which occupancy patterns and space use in an urban South African hospital impact users.

You are asked to participate in a research study conducted by Jako Nice (MArch), Gingi Khoza,Toby van Reenen, Sonya Milonova (MSc), Kevin Bingham (MArch), from the Built Environment Unit at the CSIR, and Fogarty research Grant Fellows. The results of the study will contribute to a Doctoral thesis under the University of Pretoria, Department of Architecture.

You were selected as a possible participant in this study because you are a medical staff member working in the Accident Emergency department under investigation and are in a position to comment on your experience of the patient and user flow patterns in this department.

1. PURPOSE OF THE STUDY

The purpose of the study is to determine the relationship to sampled microbiota and identification of certain organism in this hospital and the user flow and occupancy patterns as they relate to the architectural design layouts. Your hospital was issued the same brief as another hospital but the architectural design of each varies considerably.

The outcome will contribute towards the development of a microbial design guide for architects and built environment specialist to improve the potential infection risk by HAI for both retrofit and new hospitals in building design..

2. PROCEDURES

If you volunteer to participate in this study, we would ask the following of you:

1. Permission to mount data loggers that will collect temperature, humidity and CO2 in the room. And your permission to place an air sampler that will suck air onto a filter and collect organism and dust from the air twice a day for a maximum of 30 minutes at a time, and plates on surfaces twice a day for a total of 30 minutes each time.

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The investigator may be requested to leave the ward room for a period if sensitive activities or procedures are taking place.

4. POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

You, the participant, will not benefit directly or immediately from this investigation.

The potential benefit to science is to gain a better understanding of the microbial communities that exist in the South African indoor environment and the role architecture and programming plays in order to improve hospital environments in the future, to the benefit of both patients and staff.

5. PAYMENT FOR PARTICIPATION

You, the participant, will not receive payment for participation.

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The findings of this study will be published in both the doctoral thesis and scientific journals, however, the hospital and participants will not be disclosed in any publication.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact:

Principal Investigator:	Jako Nice – 0736629547, jnice@csir.co.za
Supervisor:	Prof Piet Vosloo – 012 420 4128, piet.vosloo@up.ac.za
Co-investigators:	Tobias van Reenen – TvReenen@csir.co.za
	Claire du Trevou – claire.dutrevou@gmail.com
	Sonya Milonova - sonya.milonova@gmail.com
	Faatiema Salie - faatiema@gmail.com
	Carl Morrow - Carl.Morrow@hiv-research.org.za
	Kevin Bingham - kbingham@gmail.com

9. RIGHTS OF RESEARCH SUBJECTS

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Signature of research participant or representative in cases where a participant is uncomfortable with writing

The information above was described to [*me/the participant*]

by _____ [*name of relevant person*] in_____ [*Specify the language]* and [*I am/the participant is*] in command of this language or it was satisfactorily translated to [*me/him/her*]. [*I/the participant*] was given the opportunity to ask questions and these questions were answered to [*my/his/her*] satisfaction.

[*I hereby consent voluntarily to participate in this study/I hereby consent that the subject/participant may participate in this study*] I have been given a copy of this form.

_____	_____	_____
Name of Participant	**Date**	**Signature**
_____	_____	_____
Name of Representative (If applicable)	**Date**	**Signature**

Signature of investigator/interviewer

I _____[*name of the interviewer*] declare that I explained the information given in this document to _____ [*name of the participant*] and/or [*his/her*] representative _____ [*name of the representative*]. [*He*/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in _____ [*state the language used*]. There was no need for a translator since the participant understood the language used above or this conversation was translated into _____ [*state the language*] by _____

_____	_____
Signature of Investigator/Interviewer	**Date**

CSIR our future through science University of Pretoria	**Research Questionnaire** **An indoor microbial and environmental investigation to determine the extent to which occupancy patterns and space use in an urban South African hospital impact users**	**South Africa, Western Cape, 2015** **Accident & Emergency department** **Facility** **Date** **Time** **Facility**

No	QUESTION	RESPONSE		
	Section A	**Yes**	**Unsure**	**No**
1	Confirm if you are a hospital staff healthcare worker at this facility?			
2	In which department do you work?			
3	Do you feel safe in your work environment from acquiring airborne disease? (such as TB)			
3.1	If yes response to point 2 - Why?			
3.2	If no response to point 2 - Why?			
3.3	If unsure response to point 2 - Why?			
4	Do you feel that the surfaces in your department are sufficiently cleaned for infection and you are at no risk?			
4.1	If yes response to point 4 - Why?			
4.2	If no to response point 4 - Why?			
4.3	If unsure response to point 4 - Why?			

Section B		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
5	Which week days do you work?							
6	How long is your work shift?							
7	What time does you shift start and end?							
8	Which week days are busiest in you department							
9	Which week days are the quietest in your department							
10	What times of the day (of the full 24 hrs) do you perceive are the busiest during a busy day							
11	What times of the day (of the full 24 hrs) do you perceive are the busiest during a quiet day							
Section C								
12	Which rooms in your department do you perceive to be high activity spaces							
13	What is the average total recorded number of patients in your department on a busy day (as stated in point 10) over 24 hours							
14	What is the average total recorded number of patients in your department on a quiet day (as stated in point 11) over 24 hours							

4a

CSIR
our future through science

Built Environment
PO Box 395 Pretoria 0001 South Africa
Tel: +27 12 841 4985
Fax: +27 12 841 3539

khayelitsha Hospital
Corner Steve Biko and Walter Sisulu Drives,
Cape Town, 7784
Pretoria

Attention: **Office of the CEO**

INVITATION TO PARTICIPATE IN RESEARCH

An indoor microbial and environmental investigation to determine the extent to which occupancy patterns and space use in an urban South African hospital impact users.

khayelitsha Hospital (hereafter referred to as *the hospital*) is invited to participate in a research study conducted by Jako Nice (MArch) from the Built Environment Unit at *the CSIR*. The results of the study will be contributed to a Doctoral thesis under the University of Pretoria, Department of Architecture.

This hospital was selected as a possible participant in this study because it is an urban hospital in South Africa that received matching briefs to Mithcell plain hospital but had distinctly different architectural design outcome and thus fits the case study profile.

1. PURPOSE OF THE STUDY

The purpose of the study is to determine the relationship to sampled microbiota and identification of certain organism in this hospital and the user flow and occupancy patterns as they relate to the architectural design layouts. Your

hospital was issued the same brief as another hospital but the architectural design of each varies considerably.

The outcome will contribute towards the development of a microbial design guide for architects and built environment specialist to improve the potential infection risk by HAI for both retrofit and new hospitals in building design.

2. PROCEDURES

If *the hospital* volunteers to participate in this study, we would ask the following of you:

1. Permission to mount data loggers that will collect temperature, humidity and CO2 in the room. And your permission to place an air sampler that will suck air onto a filter and collect organism and dust from the air twice a day for a maximum of 30 minutes at a time, and plates on surfaces twice a day for a total of 30 minutes each time.

   The data logger device is about the size of a cell phone and will record for 96 hour period in two seasons. This device cannot make audio recordings so no confidential conversation can be recorded. The plates are small circular Petri dishes with agar in, and the air sampler is an mechanical machine placed in the center of a room for a short time to collect Bioaerosol particles.

2. Permission for a research investigator to be present during the day from 06:00 – 18:00 in the department as unobtrusive as possible, doing hourly rounds on a fixed route: observing people using the room and counting the number of staff, patients and visitors in each room on the path.

   The purpose of the investigation is define how your department is used and how many people occupy the department over various times in the day. This person will be respectful of your right to dignity and privacy and will undertake to remain as unobtrusive as possible and will not engage with you, except to administer the questionnaire.

3. Permission for a short questionnaire to be administered regarding your perception of environment for. The investigator will issue and collect the questionnaire and be available to explain it to you if necessary. This will be have three sections as follows:

   Section A your perceptions on the infection control risk in your environment

   Section B and **Section C** is about your work schedule and the number of people in your environment.

Participants will be presented with a letter of consent to allow the above three research techniques to be implemented. They are under no obligation to give consent.

3. POTENTIAL RISKS AND DISCOMFORTS

There is potential that the presence of the research investigator may cause you to feel uncomfortable. However, the investigator is under instruction to avoid engaging with you and is to remain quiet and out of the way of normal hospital activity. The only time that the investigator is to engage with you will be to administer the questionnaire twice a day.

A number of investigators, named above, will take turns to change batteries of equipment, check recorded levels, place and collect microbial samples and take notes on an hourly walk through route that will remain the same route throughout the study, there may be a slight disturbance hourly as they make their walk through and once.

The investigator may be requested to leave the ward room for a period if sensitive activities or procedures are taking place.

The investigators will be issued with respirators by the CSIR to protect them from acquiring air-borne infections while in the hospital ward if it is deemed necessary. This can be determined by an infection risk assessment performed by the CSIR.

4. POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

You, the participant, will not benefit directly or immediately from this investigation.

The potential benefit to science is to gain a better understanding of the microbial communities that exist in the South African indoor environment and the role architecture and programming plays in order to improve hospital environments in the future, to the benefit of both patients and staff.

5. PAYMENT FOR PARTICIPATION

Neither *the hospital* nor the participants will receive payment for participation.

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_____	_____
Signature of Investigator/Interviewer	**Date**

4B

CSIR
our future through science

Built Environment
PO Box 395 Pretoria 0001 South Africa
Tel: +27 12 841 4985
Fax: +27 12 841 3539

Mitchells Plain Hospital
A Z Berman Drive, 8 A Z Berman Drive, Lentegeur,
Cape Town, 7786
Pretoria

Attention: **Office of the CEO**

INVITATION TO PARTICIPATE IN RESEARCH

An indoor microbial and environmental investigation to determine the extent to which occupancy patterns and space use in an urban South African hospital impact users.

Mitchells Plain Hospital (hereafter referred to as *the hospital*) is invited to participate in a research study conducted by Jako Nice (MArch) from the Built Environment Unit at *the CSIR*. The results of the study will be contributed to a Doctoral thesis under the University of Pretoria, Department of Architecture.

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Name of Representative	**Date**	**Signature**

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_____	_____
Signature of Investigator/Interviewer	**Date**

Ph.D. Research Proposal Ethics – protocol

Doctoral Program in the Faculty of Engineering, Built Environment &IT

Department of Architecture

Title (new)

Architecture, at a microbial nexus in Healthcare Acquired Infection;

A framework for an Architectural Design Microbial Risk Model (ADMRM)

Candidate

Jako Albert Nice

jnice@csir.co.za

Supervisor

Professor Piet Vosloo

University Pretoria

Version: Protocol 13 July 2015

Department of Architecture

Faculty of Engineering, Built Environment & IT

UNIVERSITY OF PRETORIA

Abbreviations

Abbreviation	Full wording
IAQ	Indoor Air Quality (related to pathogens)
ISQ	Indoor Surface Quality (related to pathogens)
HAI	Healthcare Associated Infection
MB	Microbial Burden
CFU	Colony Forming Units
ABC	Airborne Bacteria Count
SBS	Sick Building Syndrome
BRI	Building Related Illness
CEMS	Carbon Dioxide Evolution Monitoring System
BE	Built Environment
HVAC	Heating Ventilation and Cooling
CFD	Computational Fluid Dynamics
BIM	Building Information Modelling
SEM	Scanning Electron Microscopy
NP	Nano Particles
UVGI	Ultraviolet Germicidal Irradiation
CU	Copper
PVC	Polyvinyl chloride
HAP	Hospital associated pathogens

Abbreviation	Full wording
EA	Enterobacter Aerogenes (EA)
CRPA	Carbapenum-Resistant Pseudomonas Aeroginosa (CRPA)
MRSA	Methicillin-Resistant Staphylococcus Aureus (MRSA)
VRE	Vancomycin-Resistant Enterococcus (VRE),
TB	Tuberculosis
HIV&AIDS	Human Immunodeficiency Virus Infection & Acquired Immunodeficiency Syndrome
CRE	Carbapenem resistant enterobacteriaceae - strain-E. coli,
PA	Pseudomonas aeruginosa

Terms

Biofilm
Phenotype
Intracellular
Extracellular
Gram stain
16SrRNA
Aerobic
Anaerobic
Ecology
Micro Biome
Ion
Ionisation
Fall – out
Electrostatic
Particle charge
Space Syntax

Chapter 1

1.1. Introduction and Background

Built Environment microbiomes, Healthcare Acquired Infection (HAI) and Hospital Associated Pathogens (HAP)

The impact of the built environment on occupational comfort and wellbeing have been widely documented within the field of architecture. Margaret Campbell in her paper: *'What Tuberculosis did for Modernism: The influence of a Curative Environment on Modernist Design Architecture' (Campbell 2005)* mentions a few of the direct impacts that architecture have on the built environment and the wellbeing and health of people over the past 150 years. Looking at the rate of urbanisation and city densification, the indoor environment is becoming a greater source for health concern. Much research has been done across the world in various social settings and climatic conditions investigating healthcare associated infection (HAI) or medically termed nosocomial infection (Ducel et al. 2002) . The research outcomes point to the hospital built form being the transmitter and possible incubator of bacteria that causes various illnesses through infection.

This thesis investigates the hospital environment in an attempt to hypothesise towards the greater built environment; in order to understand and model the reservoir formation and pathogen transmission.

The way we interact in living spaces, the way that we air-seal living spaces, the way that we ventilate and clean living spaces and the material and methods we use to construct living spaces - all play fundamental parts - in the microbial make-up that architecture either advertently or in inadvertently cultivates. The postulated result: Nosocomial infection or HAI.
The spread of infectious bacteria, fungi, viruses and single cell organisms (prokaryotic & eukaryotic) specifically in hospitals are widely known to be first by human contamination (Hospodsky et al. 2012) and secondly environmental condition dependant (Eshun-Wilson et al. 2008, Basu. et al. 2007, Wolfaardt et al. 2010) etc. Therefor the presence of specific pathogenic harmful microbes that either survives and possibly proliferates in the built environment; or cultivated in humans and by interaction distributed and cross-infected to other humans, are deposited and even incubated in these environments. Given that favourable environmental conditions are provided. Hospital Associated Infection (HAI) is prevalent worldwide in health care facilities. South Africa and sub Saharan Africa with the epidemic of the human immunodeficiency virus infection & acquired immunodeficiency syndrome (HIV&AIDS) face a tougher immune deficiency challenge in the form of *tuberculosis (TB).*
Current research indicates that we might have overlooked a key area in the response to non-tuberculosis bacteria (NTB), TB and other invasive pathogenic microbes; the very microbial environment in which bacteria survives, live, are aerosolised and surfaced in. Conclusive research is required to indicate the effect and survival from aerosol to surfaces and *vice versa*.
The architectural concept: Space Syntax developed by Bill Hillier, Julienne Hanson, Philip Steadman and colleagues at The Bartlett University College London assesses spatial use based on function, user behaviour and distribution to provide a platform for evidence based research design. This model was developed for urban planning but has evolved to internal space relationship design development such as hospitals etc. (Dursun 2007, March 2002). The approach creates opportunities to model possible risk and design that considers life cycle analysis of ecosystems in Hospital environments.

The primary focus of Indoor Air Quality (IAQ) and risk has been either airborne or surface; however there exist yet another environment, the space in between these two spheres. This phenomenon is seen in the use of copper as an anti-microbial agent. A 'halo' of unknown diameter and form, related to the purity and quantity of copper has been found in sampling adjacent non Cu materials. This results in prevention of microbial growth, proliferation and formation, as is evident in the reduction of colony forming unit (CFU) count (Karpanen et al. 2012). The author presents a peer review and presented paper in the annexure on the need and lack of current research in defining the characteristics of this halo zone and even the measurability of the "ion" halo. The existence of this zone presents intriguing opportunities for study and unlocks a new area of investigation with regards to architecture, environmental risk and the use and role of materials. This thesis will investigate these possibilities.

Background to rational

Mycobacterium tuberculosis (M.Tb) is the bacterium that causes TB. TB is source based, hence only a person that produces M.Tb can transmit TB. Being of obligate airborne infection nature, people with TB disease release M.Tb through aerosols produced by coughing called droplet nuclei. The inhalation of M.Tb droplet nuclei spreads TB. Tuberculosis is clinically categorised as TB infection, TB transmission or TB disease.
TB disease can be inactive with the presence of M.Tb bacilli due to a healthy immune system. They can however become active if in contact with other infectious people increasing the number of droplet nuclei. This state of TB IS also known as latent TB infection (LTBI). One in ten people develop TB diseases that have LTTB infection (Bock et al. 2007). TB disease occurs predominantly in the lungs and a person with TB disease may be an active M.Tb producer. It can however also manifest as meningitis and in organs, IRIS, spine etc. There are differing strains of TB, relative to their drug resistance, they are categorised as M.Tb, multi drug resistant (Mdr) TB and extensively drug resistant (Xdr) TB and recently Total drug resistant (Tdx), Tdx and Xdr TB strains being the most concerning.

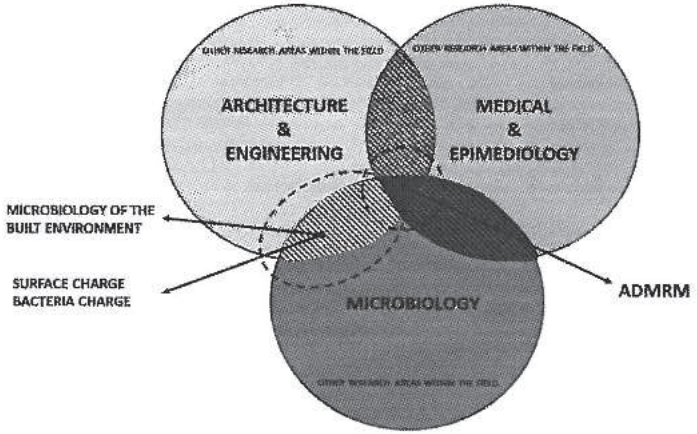
It is evident that TB is a global problem and an epidemic in South Africa. The nature of TB infection by airborne makes all actively infected, latent infected ill people with an immune deficiency disease i.e. HIV, unsuspected patients, health workers or healthy people all potential victims of TB. Studies seem to indicated that health care facilities are contributing to the spread of TB bacteria (Eshun-Wilson et al. 2008) South Africa is ranked the worst infected country in the world (per capita) of *Mycobacterium tuberculosis* (WHO. 2009a). As far as Mdr and Xdr TB are concerned *"South Africa is the third highest tuberculosis burden country in the world, lagging behind two countries, China and India, who have significantly larger populations than ours"* (Motsoaledi, Norbert 2011). The epidemiological burden of TB and HIV co-infection in South Africa is estimated at 70% + (WHO. 2009a). The growth of drug resistant strains of TB, compounds the heavy burden of TB in South Africa. Numerous organisations such as: World Health Organisation (WHO), Centre for Disease Control (CDC), Council for Scientific and Industrial Research (CSIR) etc. in partnership with the South African National Department of Health are contributing to address the epidemic facing South Africa and other parts of the world. In South Africa out of every 100 000 people, 768 are TB positive (WHO. 2011). The unconfirmed cases might well be far in excess and of those confirmed cases 70% (as noted above) have HIV Aids. It must be notes that more than 5.5 million people in South Africa have HIV Aids and are thus highly susceptible to TB due to the immune co-relationship that these diseases share. These statistics points to the exposure and the unsuspecting healthy people, patients in hospital environments and public settings. The rate of incidence and prevalence locally are still on the increase, however the growth rate is positive and reflect a slow decline annually (WHO. 2013). With little research in building design, social anthropology and financial backing this epidemic of TB will continue to impact the lives of millions locally and globally.

The WHO has recently done a study within the South-East Asia, Europe, Eastern Mediterranean and Western Pacific areas (2009). The outcome reflected that "8.7% of hospitalised patients suffer health care associated infection". The study concluded that worldwide up to "1.4 million people suffer from infectious complication acquired in Hospitals" (WHO. 2008). "In South Africa TB has become a driver in nosocomial infection. One such case study: The "Tugela Ferry TB outbreak in 2005-2006" recorded 8 deaths of hospital staff as a conclusive result of nosocomial infection. "Hospital transmission was a major factor" (Koenig 2008)
"There is growing evidence that institutional transmission is a critical factor in epidemic HIV-associated TB and MDR-TB. Infection prevention and control (IPC) is only now becoming a feature of the global strategy to control TB. In South Africa, IPC remains the responsibility of individual healthcare facilities. There is an urgent need to obtain data on nosocomial transmission" (Sissolak, Bamford & Methar 2010). Studies have been done by staff at Tygerberg Academic Hospital among their own staff to ascertain the impact of nosocomial infection (Eshun-Wilson et al. 2008). The studies were done over an 11 year period and the infections totalled over 130 health care worker infections. Similar studies in Kwa-Zulu- Natal by (Naidoo, Jinhabhai 2006) over the period of 5 years, 1999-2004 indicated "1133 per 100 000 health care workers" (HCW) were infected by TB (Naidoo, Jinhabhai 2006) Similar studies that have been conducted globally all point to the same concern, nosocomial infection has major implications on the most precious health resource South Africa and other countries have: the health care worker.

Background to rational Continued

This section is still to be completed with all relevant paper reference evidences.
The increase in hospital acquired infections (HAI) in hospitals (Eames. et al. 2009) and the cost burden on government is immense. This has been quantified in various countries globally (Klevens et al. 2007b, Mendell. et al. 2002) but not in South Africa, due to the burden of disease and levels of poverty (Motsoaledi, Norbert 2011, WHO. 2009b, Koenig 2008), it is likely to be far in excess of the some international statistics per capita. It not only impacts financially but it also impacts the general health condition of communities (Murray. 2004). In the current era of HIV and TB in South Africa the impact of immune compromised patients by HAI is deadly (Marais et al. 2006, Nyamogoba et al. 2012, Fennelly 2007), it only worsens the fight against these diseases (Koenig 2008). South Africa is not limited by the two major disease burdens of HIV and TB, but also others impact the immune compromised individuals. As indicated in the table below. Mendell et al. communicates the current state of the United States health cost condition: 'Available data suggest that improving building environments may result in health benefits for more than 15 million of the 89 million US indoor workers, with estimated economic benefits of $5 to $75 billion annually. (Mendell. et al. 2002). The following statistics reflect estimated USA cost burdens and economic impact in 2002: ten billion dollar annual health care cost, nineteen billion dollar annual work absence cost, three billion dollar annual reduced performance loss cost. (Mendell. et al. 2002).
This represents an alarming cost to government condition, fuelled by HAI, it is evident that both surface and air plays a defining role in the health and wellbeing of patients and visitors. And hence good Indoor Air Quality (IAQ) and Indoor Surface Quality (ISQ) are required to reduce the above mentioned costs and improve environmental conditions.

Built environment micro biomes – 'Bio-informed design'



A field of study that has been developing in recent time sheds a new perspective on the built environment: The microbial environment. Architects and engineers without conscious consideration have been designing these environments for centuries. The "microbial landscape" or "built environment micro-biome" are under research by amongst others, ecologist Jessica Green and fellow researchers from the University of Oregon and the Santa Fe Institute. To quote from a recent paper presented by this team of researchers:
'Just as we currently manage natural ecosystems to promote the growth of certain species and inhibit the growth of others, an evidence-based understanding of the ecology of the built environment microbiome opens the possibility that we can similarly manage indoor environments, altering through building design and operation the pool of species that potentially colonize the human micro- biome during our time indoors' (Kembel et al. 2013).

In March 2014 the American Association for the Advancement of Science (AAAS) held a symposium in Washington DC, USA to bring light to this fast growing research subject to involve leading researchers to contribute to this think-tank. Currently this field of research is driven by three major organisation/institutions with funding from either Sloan foundation or the American Government. Organisations involved are: BioBE – Jessica Green and colleagues (Oregon state University), Hospital Biome project (interdisciplinary team of researchers), microBEnet site and research driven by Jonatham Eisen at UCL Berkley and Hal Levin, with other research parties in Toronto Canada: Jeffrey Siegel at Toronto University. This research also connects with the Human biome research project that has been running for some years. The most current think-tank is to take place in Hong Kong, at the ISAQ – Indoor Air conference and Sloan symposium on the built environment.

The built environment is host to vast variety and quantity of mycobacteria. The human spends most of his time - nearly 85% - within these environments. Over time we have adapted and engineered these environments so suite our comfort and our needs. What we have neglected to consider are the environments invisible to the naked eye that we have created which impact on our health (Hospodsky et al. 2012, Rintala et al. 2008). Similar to the deductions that Margaret Campbell has made (Campbell 2005), researchers from the Environmental Health Department, National Public Health Institute in Helsinki, Finland have begun quantifying and defining these facts in their paper: *'Diversity and seasonal dynamics of bacterial community in indoor environment.'* (Rintala et al. 2008).
Biomes: _ *'as for any other biome, the composition of the built environment micro biome is determined by some combination of two simultaneous ecological processes: the dispersal of microbes from a pool of available species and selection of certain microbial types by the environment* (Kembel et al. 2013).
Man has created environments that consequently become the production of human pathogenic microbes by cancelling out 'competitive exclusion' through the various methods of sterilisation. The result is removing the later part of the ecosystem, but forgetting that he himself is the host to the most harmful pathogens. Architecture and the microbial environment are not separated, but in fact intimately fused.
Can one combine current architectural research in space syntax with environmental risk and microbial growth knowledge and theory as design tools towards developing real world health guidelines in building design?

This thesis postulates the possibility to develop a dynamic tool that incorporates space syntax, risk models (sampling and theoretical) for surface and airborne contagion and microbial interaction that could generate an architectural theory and system of design that can be used for validation and guidance towards a health conscience design.

The following is a preliminary abstract of interdisciplinary paper collaboration by the author – an architect and a microbiologist Phd candidate researcher in Toronto Canada. It discusses and explores the research, focus and purpose for the built environment microbiome; the data and concept will be used to develop the microbial theory for design in the architectural microbial model:

Built form surfaces as culture source for biofilm hosting, causative of Hospital Acquired Infection, however likewise a potential source for competitive Environmental Mycobacteria.

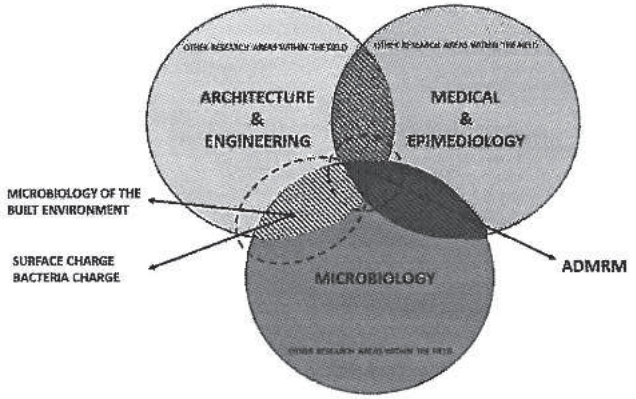
The increase in hospital acquired infections (HAI) in hospitals (Eames. et al. 2009) and the cost burden on government is immense, this has been quantified internationally (Klevens et al. 2007b, Mendell. et al. 2002) but not in South Africa, due to the our burden of disease and levels of poverty (Motsoaledi, Norbert 2011, WHO. 2009b, Koenig 2008), it is likely to be far in excess of the some international statistics per capita. It not only impacts financially but it also impacts the general health condition of communities (Murray. 2004). In the current era of HIV and TB in South Africa the impact of immune compromised patients by HAI is deadly (Marais et al. 2006, Nyamogoba et al. 2012, Fennelly 2007), it only worsens the fight against these diseases (Koenig 2008). South Africa is not limited by the two major disease burdens of HIV and TB, but other that prey on immune compromised individuals. Some of these noted for this study are: NTB/NTM - Pseudomonas Aeruginosa, Staphylococcus aureus, Acinetobacter baumannii, M. fortultum, M. chelonae, M. abscessus; Legionella, Protozoa, Pneumocystis jiroveci Pneumonia etc. (Morris, Harrison 2003, Nseir et al. 2002, Taylor, Ross & Bentham 2009, Nevez et al. 2008) Literature refers Pneumocystis jiroveci Pneumonia the most common and bacterial infection. It must be noted, that this list contains both bacterial and fungal (spore) species. Each of these species poses a health threat to an unsuspecting visitor or patient, and more critical an immune suppressed patient or undiagnosed TB patient.

In a paper written by Kremer, Schewebke & Kampf: How long do nosocomial pathogens persist on inanimate surfaces? A systemic review (kremer, Schewebke & Kampf 2006). A systematic literature review was conducted on the persistence pathogen survival on surface, however some of the reference data are outdated and needs to be substituted with more recent studies. It nevertheless communicates the importance of understanding the microbial environment and its role as incubator. Wolfaardt in a paper: Integration and proliferation of Pseudomonas aeruginosa PA01 in multispecies biofilm (Wolfaardt. et al. draft), describes this survival and dispersal methods of pathogens using Pseudomonas aeruginosa as sample type.
This requires architects and designers, engineers, construction managers and policy makers to understand the interaction between organisms and the built environment, the inhibition and or proliferation of pathogens. There is a notable difference between Lab culturing theory and wild type culture: practical site testing and experimentation. A large portion of the current microbiological theory we know originates from lab cultures and does pose questions as to the "reality" relationship with a much wider variety of environmental impacts and considerations. It is most appropriate for understanding behaviour but it is time that multi-disciplinary teams get involved in site based /wild type analysis and exploration.
The understanding of pathogenesis, the presence and formation of biofilm appears to be the critical question. Can species co depend and thus manage to survive in high stress environments such as hospitals (Wolfaardt. et al. draft, Taylor, Ross & Bentham 2009) The nature of biofilm survival and the persistence on material types and environmental conditions needs further in depth research, various researchers have initiated this investigation (kremer, Schewebke & Kampf 2006, Kolter, Siegele & Tormo 1993, Kolter, Greenberg 2006, Ronan et al. 2013)

The possibility and methodology of bacterial communication: quorum sensing is discussed by De Kievit, Kolter and other (De Kievit, Iglewski 2000, Kolter, Siegele & Tormo 1993) this fascinating discovery asks a striking question to the Architect, engineer and policy maker: Do we create environments by our choices of material, ventilation systems, spatial layouts and simulated environmental conditions that stimulate the "activators" or "receptors" that trigger communication sensing between bacteria (Kolter 2010, Claesson 2010); in so doing cause them to either proliferate or go into a desiccate state of survival. Various studies indicate this behaviour of microbes under certain stress conditions; we need to compare these conditions to our built environment. (Parsek, Fuqua 2004, Ronan et al. 2013). Researchers De Boer et. Al. in their study for Pneumonia outbreaks in renal patients has published a paper: An outbreak of Pneumocystis jiroveci Pneumonia with 1 predominant Genotype among Renal Transplant Recipients: Inter human Transmission or a Common Environmental source.

In understanding this communication, survival, proliferation of bacteria one can now postulate beyond the known: Do probiotic walls, non-sterile walls and surface promote or inhibit the persistence of bacteria. Which elements in the material surface benefit or inhibit the growth, which sources activates the sensors for colony formation or deactivation further cultivation; these are critical architectural considerations and questions for public health.
To investigate these questions a multi-disciplinary team consisting of both an architect and microbiologist pose some explorative questions for experimentation: Dry biofilm experimentation, the condition of high desiccate biofilm formation a similarity to inanimate surfaces in environments such as hospitals. PhD candidate Wendy Stone proposes a Carbon dioxide evolution monitoring system (CEMS) experiment to evaluate biofilm life activity on the basis of CO2 measurements; this will be done for various HAI bacteria. It will be tracking the metabolic rate and thus evaluate the life activity of the bacteria/biofilm.

Now if one evaluates these finding with regards to other surface types it will allude to the specification of surfaces that either prevent growth, the cleaning of surface to reduce growth and nutrient intake or the probiotic surface that promotes growth in the sense of outcompeting with another non-pathogenic bacteria such as Bbellovibrio bacteiovorus (Chang. et al. 2011). If these organism do survive, what is the method of survival and feeding, Experimentation will allow us to systematically define the source and origin of their

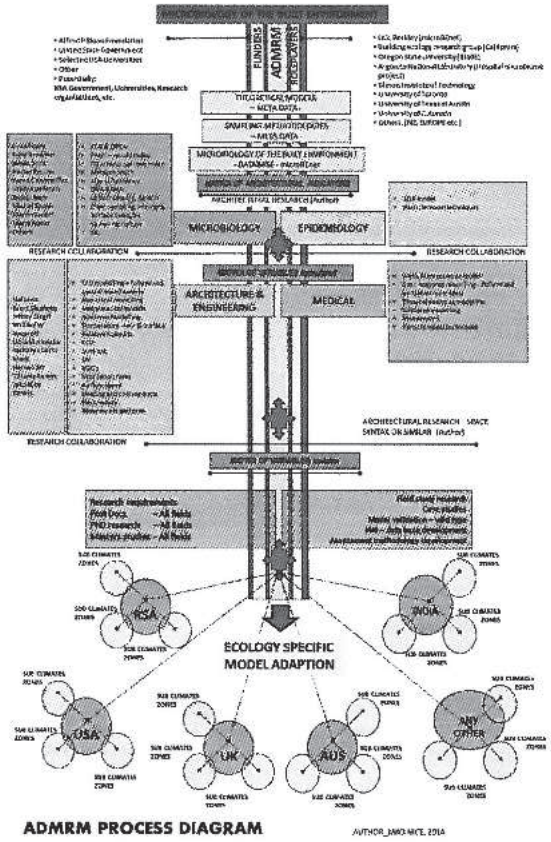


survival based on the stress characteristics of the environment and surface; in addition defining the environment and possible surface type permits development of a chart or matrix of colony formation related to illness, environment and material.
Where does this leave us: It is evident that architecture and design needs to be informed as to the conditions we are creating and effects of those conditions on our health, a quantification of bacteria and their habitat. This collaboration between Architecture and microbiology is the start of a evidence base for a scientific methodology towards Architectural design and in depth multi-disciplinary research, in developing a consciousness for health in architecture and establishing a new architectural theory within the ecology of building design: ***'ecology of architecture: An empiric microbial design construct'.***
The microbiome concept is still in its infancy: (Rintala. et al. 2008, Michel et al. 2012, Kembel et al. 2013). To continue in their search: How do we establish a relationship and interaction between the environment and the built form: Building ecology, unless one understand the factors and role players that make-up this environment.

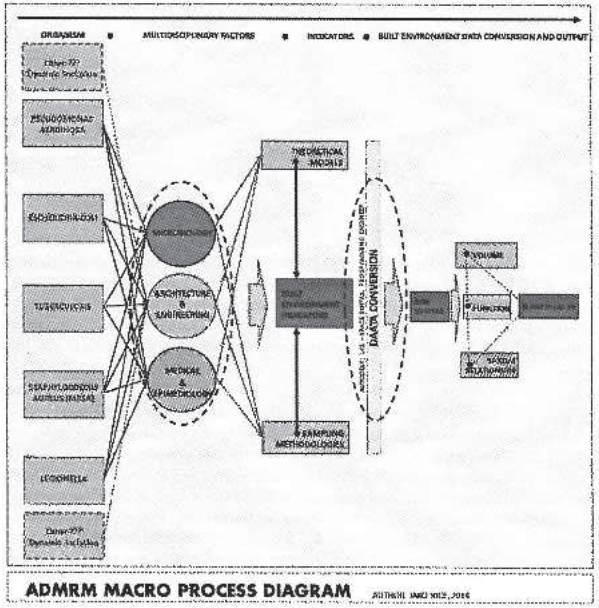
The noted statistics and environmental characteristics - pertaining to South African and international disease epidemics, indoor environments, health care associated infection and the relationship with the microbial environment presents the opportunity to investigate and develop quantitatively the current conditions of the "harmful" or "sick building" and their microbial environments in defining the influential environmental factors, quantifying risk, spatial design relationship and material selection brings us closer to healthy buildings and indoor environments.

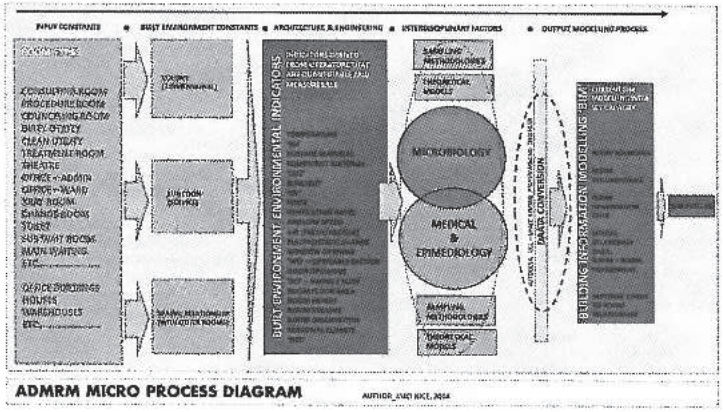
Chapter 2

2.1. Experimental protocol and project overview



Research Project outline & Central research concept





Focused research investigation
Mathematical architecture space syntax theory

Chapter 3

3.1.1. Microbial Experiment Proposal

3.1.2. Problem Statement

What benefit is there in studying the biome of an indoor environment? or.....Do we know the health impact of our planning and construction decisions on building users?
Both these questions are inherently the same question. We need to know the ecology of our indoor environment that we may know the impact of our decisions. Studying the indoor biome, studying the human body and studying the methods of bacteria transmission provides tools for designers to relate human health to design planning and space creation.
We do not know what constitutes the indoor biome of any given indoor environment in South Africa, even less a Hospital and more specific an accident and emergency unit (a zone high occupancy and through put of acutely ill people). Due to this fact one cannot relate the suggested design and implemented ventilation strategy or the architectural planning program to the prevalence of certain bacteria organisms in that environment based on its occupancy load. The relationship with bacteria prevalence and architectural planning in user programs have not been studied, yet people are the single largest contributor to bacteria in indoor environments, making the indoor environment a conduit for pathogens.
The implementation of 'green' design principles and the subsequent building regulations do pose health impacts on the wellbeing of patients and users form a transmission perspective; we can measure the energy consumption and the water and waste use, but we cannot relate that to the building biome and health and hence user risk. A study such as this will highlights the need for microbial environments surveillance as part and parcel of the full building system in considering sustainable design.
The impact of airborne disease specifically TB and the co-relationship to HIV can be related to the conditions of indoor environments. The ventilation requirements and the methodology of space use play a fundamental role in the transmission of disease, not only airborne but also touch surfaces.
Compromised patients suffering from HIV (5milj +, of which 70%+ have TB in the WC) are presented with environments that carry airborne TB nuclei and other forms of surface associated bacteria pathogens. The cost to clean and dilute air in these environments have a substantial financial impact on already constrained budgets, in addition developing world countries face the challenges of power outage, poor maintenance, cost and escalation to mention but a few; a sustainable solution needs to be designed into buildings to reduce cost, and promote sustainable infrastructure while providing equitable safe low risk environments for all patients.

3.1.3. Experiment Hypothesis

Microbial experiment hypothesis
The study of the composition of the built environment indoor microbiome and the presence of pathogenic bacteria will provide evidence for co-relationships between the indoor environment conditions, occupancy and the architectural planning program. Postulating potential user health risks emanating from Architectural design planning.

Related hypotheses...

Observational experiment hypothesis: *Observational space analysis provides potential means to study human interaction and functional space use, programmed flow patterns and occupancy duration. Postulating that observational analysis can be utilised (considering disease transmission)*

with investigations of the static indoor environment conditions and the indoor microbial environment to proof the causal health impact of architectural design program and planning.

Environmental experiment hypothesis: *Unremitting monitoring of indoor environmental conditions of the built environment provides potential data that can be correlated to occupancy patterns, functional space use patterns and sustainable conditions for the existence and persistence of microorganism. This study postulates that studying by continuous monitoring of CO2, Temperature and humidity one can provide data that can be attributed to occupancy increase or decrease (architectural planning efficacy and transmission risk), the presence and the persistence of pathogenic organisms (potential environments prone to transmission of disease by incubation)*

3.1.4. Experiment

3.1.5. Environment:

1. A&E – Khyalitsha Hospital – Hospital A
2. A&E – Mitchells plain Hospital – Hospital B

3.1.6. Pre sampling test

1. Prior to sampling a sampling test run will be done, to determine the efficacy of sampling once, twice or three times daily. This will be done twice in a week: at peak and at low occupancy (which will be determined by a questionnaire based on the staff perception) to determine the impact of different sampling days and sampling quantity. Lastly this will be done at one of the two hospitals only, as it should provide sufficient data for final experiment resolution.
2. Day 1 – sample 3x in a single day for a single facility (This will be done for plate and air)
3. Day 2 – sample 2x in a single day This will be done for plate and air)
4. Day 3 – sample only one This will be done for plate and air)
5. Based on the outcome of the proposed pre experiment – Do we find large variation in the different sampling regimes or can a single or two samples be accepted as statistically significant representation of the biome for a day, this will determine the sampling frequency.
6. Based on the variation in services offered each day of the week, and thus a direct impact on the patient profile over the various days, the frequency in number of days within a seven day week will require sampling consideration.

3.1.7. Number of rooms

1. The study focuses on the emergency unit of 2 hospitals in Cape Town. Preference is given to high travel zones with most through put of patients, HCW and staff.
2. 5 zones of similar clinical service and or function have been identified in each Hospital.
3. See attached the floor plan of the selected zones of study.

3.1.8. Sampling types

1. **Settling plate** (Standard microbiology methodology and equipment will be used, with existing techniques, we refer to the following papers and other as guidance: see also reference list (duration of plating (15 min – 45 min require guidance on duration and the planned or expected findings related to that), type of storage, period before analysis, specific environmental

conditions at the time and during the time of collection, room volumetric, design analysis of space, quanta of people moving through the space) type of agar to be determined (use MXIS BE standard set if possible)

2. **Air sampling** (Standard microbiology methodology and equipment will be used, with existing techniques, we refer to the following papers and other as guidance:(Chunyang et al. 2015) see also reference list
    a. Type A: (duration to be determined by professional and literature estimate 30min per sample), type of storage, period before analysis, specific environmental conditions at the time and during the time of collection, room volumetric, design analysis of space, quanta of people moving through the space) type of agar to be determined (use MXIS BE standard set if possible). The selected sampling type: flat membrane filter small enough in size for bacteria collection 5 micro millimetres in size.
    b. Type B: fluorescent particle counter, utilising air sampling methodology with real time particle counting analyses for total particle count. The fluorescent particle counter detects biologic particle concentrations using a fluorescent particle counter. Position and placement: at a height of 1.1 m and was 1.5 m away from solid stationary objects. Samples to be collected at a flow rate of 28.3 L/min for 5 minutes. The recommended experimental settings: the flow rate was 1.0 L/min, the ultraviolet current was 1.46 A, and the photo multiplier tube voltage was 550 V. The counter sample is continuously and records the number of biologic particles

3.1.9. **Experiment Purpose**

1. To determine the total community present in the given environment using both the plate sample collection as well as the various air sample collection. The analysis will be done using pyrosequencing and real time fluorescent particle counting. (total number of organism and identification of the organism - thus community identification)
2. To determine whether the specific high burden HAI bacteria are present in these environment. As per the specified the table below, this includes 2 commonly found on surfaces, and 2 commonly found in the air ...These are the most common US nosocomial infection, included Pneumocystis and TB for respiratory purposes, to the knowledge of the author such a list has not yet been developed for South Africa. Utilising PCR to identify the specific bacteria and the presence of all related Geno types in the sample.

Staphylococcus aureus
Pseudomonas aeruginosa
Pneumocystis carinii pneumonia (PCP)
Mycobacteria Tuberculosis

3.1.10. **Sampling Duration**

1. The sampling will be conducted over 2 seasons, as Cape Town represents based on weather data in effect two seasons: Winter and Summer

2. 4 days, for the summer season 2x per day for each Hospital at the same time (settling plates, air sampling), the duration of each sample period is still to be developed based on accredited sampling methods.
3. 4 days, for the winter season 2x per day for each Hospital at the same time (settling plates, air sampling), the duration of each sample period is still to be developed based on accredited sampling methods.

3.1.11. **Number of samples**

1. **Settling plates** – total 160

- KH Hospital A (5 zones) , platting twice a day: at 08:00 and at 16:00; for 4 days; over 2 seasons
    a. Total: Winter – 40, Summer 40
- MP Hospital B (5 zones) , platting twice a day: at 08:00 and at 16:00; for 4 days; over 2 seasons
    a. Total: Winter – 40, Summer 40

2. **Air samples** – total 160
   This will match the settling plate routine central in each zone

- KH Hospital A (5 zones) , sampling twice a day: at 08:00 and at 16:00; for 4 days; over 2 seasons
    a. Total: Winter – 40, Summer 40
- A&E : MP Hospital B (5 zones) , sampling twice a day: at 08:00 and at 16:00; for 4 days; over 2 seasons
    b. Total: Winter – 40, Summer 40

3.1.12. **Analysis**

1. PCR and Pyrosequencing
2. Specific taxa with total gene pool for each sample using PCR analysis for each of the four elected bacteria
3. Pyrosequencing of each sample to determine the full community and quanta of each present in the sample

Staphylococcus aureus
Pseudomonas aeruginosa
Pneumocystis carinii pneumonia (PCP)
Mycobacteria Tuberculosis

4. Total testing by PCR: 320 x 4 = 1280 samples
5. Total testing by Pyrosequencing: 320 x 1 = 320samples

3.1.13. **Assistance**

1. 1x B4 Technician – (this is for both facilities) for setting out plates, collecting plates, included returning samples to the lab.

2. Total time required: 4hrs per day for 14 days: 56hrs total.
3. This will be carried out by a approved and certified company (collection and analysis)

3.1.14. **Sampling options**

a. **Option A – Full time 7 days, Air sampling and plate sampling**

This is the ideal full study period - (Includes all the sampling variations options and analysis proposed above) however this will be to expense and due to cost this option will not be viable.

b. **Option B – 4 day sampling, Air sampling and plate sampling**

Why? (Due to the variation in efficacy of swab sampling, and considering cost of analysis the potential benefit of swab data could be discarded. in addition considering the peak high and peak low periods for the A&E department could enable considering less days to still provide a statistically significant sample. This presents cost and time savings (considering maximum post sampling pre analysis storage period) .

3.1.15. **Experiment Delineation**

- The proposed study site is limited to the Accident Emergency unit only, and hence findings will be delineated to this environment, it could or could not represent the larger hospital.
- The selected rooms represent the accepted high and medium traffic movement zones in the selected department. Low /limited use zones are not considered based on the possible risk they could represent in relation to the larger department.
- The organisms selected for culture analysis are based on literature studies and most common HAI including high burden airborne disease bacteria as per USA statistics and diseases burden as per WHO report for South Africa - TB. Due to the cost of analysis other organism are not considered in this study, however the full taxa by PCR analysis will indicate potential gene line representation in the environments and thus most likely illuminating related HAI organism.
- Only settling plates and air sampling will be used for bacteria sampling.
- Approved and accepted certified collection, and analysis techniques will be utilised in so doing meeting ISO standards and standard microbiological methodology per bacteria type.
- Sampling duration is based on accepted standards and the pre study results guidance to statistical significance as well as guidance from other studies. See reference list below.
- For air sampling it will be assumed that the room air represents a well-mixed environment, and where mechanical ventilation has been utilised maintenance logs will be will be used to confirm the airflow speed, fresh air quantity, air changes per hour and the pressure differential in certain rooms.
- This experiment provides sampling for a maximum of 4 days only per season, this is due to cost of analysis, and the distribution of days will be determined by peak and low peak times based on pre testing and questionnaire results.
- This experiment considers only 2 seasons as representational of the full variation of climatic conditions over a year in this climatic region.

3.1.16. **Research project objective**

1. It is an accepted fact that indoor environments have the potential to harbour bacteria that are dangerous to human health (pending various factors for airborne and surface); it is an accepted fact that humans are the main source of pathogens in indoor environments (airborne and touch).
    a. To define the distribution of bacteria related to space use and design program.
    b. To understand the relationship of indoor environmental conditions and the persistence of harmful bacteria in indoor space.
2. To relate microbial risk to architectural design for future and existing design guidance. This investigation provides the first data on the South African microbial biome, and specifically in a high burden and transient patient healthcare environment.
3. To analytically compare spatial design layouts with the microbial load distribution and community diversity in both case study hospital sites.
4. To identify risk patterns in design planning (identify and establish universal environmental markers) through investigating microbial community and diversity distribution.

3.1.17. **Value**

1. That architectural design impacts (by secondary nature) user health. Studying the indoor environment enables the designer to consider (as he would consider green systems for energy conservations), building systems and design layout for human health.
   This study contribution intends but not limited to:
    a. Providing evidence that the indoor biome of an environment directly relates to is user, and is a direct consequence of its functional use; more so in hospital environments where function largely determines form and flow.
    b. Providing evidence that spatial configuration do have an impact on disease spread, due to the social engineering aspect of people distribution, the subsequent design can be potentially reviewed and adapted to reduce risk and or restrict disease spread.
    c. Associate and relate human health to environmental risk considering design, providing a platform for intelligent design review tools.
    d. A design tool that informs the designer that his planning layouts presents potential high risk zone, giving guidance as to how do to make changes and guide staff on the most appropriate clinic program within the given building envelope.

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Chapter 4

4.1. Environmental Experiment Proposal

4.1.1. Problem Statement

As designers and built environment specialist we do not fully understand the impact of material choice, architectural planning, building orientation, design typology and even space planning on indoor environmental conditions of the built environments. Studying in real time on a continuous basis 'building life' characterised by elemental parameters such as CO2 levels, temperature fluctuations and levels of relative humidity provides critical data on the way buildings live and breathe in their environment and respond to their users, the ecosystemic conditions they produce and hence provide to microorganisms.

HAI, nosocomial infection and sick building syndrome stems from the very indoor environments man creates and programs for occupancy. This study postulates that it is not only human biology that drives disease transmission, but that the potential for disease transmission can be attributed to both indoor building conditions and the planning program. Studying this relationship between program and indoor conditions provide guidance and evidence for a user health based informed design. The elemental parameters such as CO2, temperature and relative humidity provides clues to the relationship with microorganism prevalence as stated below and occupancy flow and user patterns as stated below. The collective study of these variables by real-time environmental monitoring will provide guidance to building design and managing building related health risk.

With partial reference to the Microbial Experimental Proposal document version 1:

"What benefit is there in studying the biome of an indoor environment? or..... Do we know the health impact of our planning and construction decisions on building users?

Both these questions are inherently the same question. We need to know the ecology of our indoor environment that we may know the impact of our design decisions. Studying the indoor biome,

studying the human body and studying the methods of bacteria transmission provides tools for designers to relate human health to design planning and space creation.

We do not know what constitutes the indoor biome of any given indoor environment in South Africa, even less a Hospital and more specific an accident and emergency unit (a zone with high occupancy and through put of acutely ill people). Due to this fact one cannot relate the suggested design and implemented ventilation strategy or the architectural planning program to the prevalence of certain bacteria organisms in that environment based on its occupancy load. The relationship with bacteria prevalence and architectural planning in user programs have not been studied, yet people are the single largest contributor to bacteria in indoor environments, making the indoor environment a conduit for pathogens.

The impact of airborne disease specifically TB and the co-relationship to HIV can be related to the conditions of indoor environments. The ventilation requirements and the methodology of space use play a fundamental role in the transmission of disease, not only airborne but also touch surfaces. "

With partial reference to the Observational Experimental Proposal document version 1:

"The role of spatial design and functional room location relates to design and user program, which in turn directly impacts user interactions. These interactions could potentially be responsible for cross infectious conditions. When studying the science of bio-aerosol flow, pathways and aerosol transmission from person to person and space to space; the space use and layout contribute as a mitigating factor. " "A 'real time' space use (function and flow) by observation and analysis can be utilised to understand and predict human interaction and space use by objective evidential means. A combined study of spatial observation with environmental data logging and microbial sampling could potentially provide tangible interrelationship correlations between risk, environment and space use."

4.1.2. Experiment Hypothesis

Environmental experiment hypothesis
Unremitting monitoring of indoor environmental conditions of the built environment provides potential data that can be correlated to occupancy patterns, functional space use patterns and sustainable conditions for the existence and persistence of microorganism. This study postulates that studying by continuous monitoring of CO2, Temperature and humidity one can provide data that can be attributed to occupancy increase or decrease (architectural planning efficacy and transmission risk), the presence and the persistence of pathogenic organisms (potential environments prone to transmission of disease by incubation)

Related hypotheses...

Observational experiment hypothesis: *Observational space analysis provides potential means to study human interaction and functional space use, programmed flow patterns and occupancy duration. Postulating that observational analysis can be utilised (considering disease transmission) with investigations of the static indoor environment conditions and the indoor microbial environment to proof the causal health impact of architectural design program and planning.*

Microbial experiment hypothesis: *The study of the composition of the built environment indoor microbiome and the presence of pathogenic bacteria will provide evidence for co-relationships between the indoor environment conditions, occupancy and the architectural planning program. Postulating user health risks emanating from Architectural design planning.*

4.1.3. **Experiment**

4.1.4. **Environment:**

3. A&E – Khyalitsha Hospital – Hospital A
4. A&E – Mitchells plain Hospital – Hospital B

1.1. Pre sampling test

7. Prior to sampling/logging a sampling test run will be done for a single day (24 hrs), to check the feedback of the loggers, the weather station and a test run the software with the data collected.

4.1.5. **Number of rooms/zones**

4. The study focuses on the emergency unit of 2 hospitals in Cape Town. Preference is given to high travel zones with most through put of patients, HCW and staff. This study will asko include a ward at each hospital.
5. 5 zones of similar clinical service and or function have been identified in each Hospital in each department.

4.1.6. **Sampling types**

3. **Data Logger** – a single manufactured unit by CO2Meter, Inc. Ormond Beach Florida United States, Unit type - CM-0018AA.
   The unit includes built in sensors collecting CO2, Temperature and relative humidity data as well as date and time stamp. The loggers are placed either on a surface approximately counter height: 900mm or will be suspended in the air at 2100mm. The data is recorded via SD Card that will be disseminated on completion of the investigation using GasLab® software – as provided by the manufacturer of the data loggers. The expected battery life of the unit is +- 4-5 days. This will be checked by the assistant to prevent data loss due to uncalculated power down time.
   a. **Temperature** ± 2 °C over full temperature range; Sampling rate: > 1 Hz logging at 1 minute intervals
   b. **Relative Humidity** ± 5% RH over full temperature range; Sampling rate: > 1 Hz logging at 1 minute intervals
   c. **CO2** - Sampling Method: diffusion; non-dispersive infrared (NDIR); Measurement Range: 0 – 2,000 ppm (0-0.2%); Accuracy: ± 50ppm ± 2.5% of measured value; Sampling rate: > 1 Hz logging at 1 minute intervals
4. **Weather Station** - Ambient Weather WS-1001-WIFI OBSERVER Solar Powered Wireless WiFi Remote Monitoring Weather Station; http://www.ambientweather.com/amws1000wifi.html
   1. **Outdoor temperature** (weather station)
   2. **Outdoor wind direction** (weather station)
   3. **Outdoor wind speed** (weather station)
   4. **Outdoor CO2** (weather station)
   5. **Outdoor Relative Humidity** (weather station)

   Further information such as communication, feature, accuracy and data collection are indicated in the supplier's manual.

1.2. Experiment purpose

To determine the relationship between CO2 levels, humidity and temperature; on occupancy, design and planning as related to the prevalence of microorganisms in an environment. Findings correlated with the outdoor conditions due to the direct impact on naturally ventilated environments.

1.3. Sampling Duration

4. The Relative humidity, temperature and ambient CO2sampling will be conducted over 2 seasons, as Cape Town represents based on weather data in effect two seasons: Winter and Summer
5. 4 days, for the summer season 24hrs per day for each Hospital at the same time.
6. 4 days, for the winter season 24hrs per day for each Hospital at the same time.

1.4. Number of samples

3. **Data loggers**

- KH Hospital A (5 zones) , 1x loggers per zone, 2 departments for 24 hrs, for 4 days in winter and summer
  a. Total: Winter – 96 hrs (Temperature, Relative humidity and CO2), Summer 96 hrs (Temperature, Relative humidity and CO2)
- MP Hospital B (5 zones) , 1x loggers per zone, 2 departments for 24 hrs, for 4 days in winter and summer
  a. Total: Winter – 96 hrs (Temperature, Relative humidity and CO2), Summer 96 hrs (Temperature, Relative humidity and CO2)

4.1.7. **Analysis**

6. Using GasLab® software – as provided by manufacturer of the data loggers.
7. This will provide information to the average CO2, Temperature and Humidity in each of the zones measured by the loggers.
8. Correlating this data with the observational data will indicate reason for reduction or increase in any of the variables as measured by the data logger. This can be further correlated with the data collected by microbial samplers placed in the same zones and regions as the data loggers and related microbial composition to the measured environmental factors and the spatial occupancy and usage.
9. Statistical analyses assisted by CSIR statistical analyst to determine the significant relationships and correlation of the various data collected. Specific analysis to be confirmed at a later stage.

4.1.8. **Assistance**

4. 1x Technical assistant – (a single facilitator will be required for both facilities) for setting up the data loggers, testing and checking battery life and finally removing upon completion of study.
5. Total time required: 4days per day season: 8 days total.

4.1.9. Experiment Delineation

- The study site is proposed for the Accident Emergency unit only, and hence findings will be delineated to this environment, it could or could not represent the larger hospital.
- The selected rooms represents the accepted high traffic zones in the selected department and thus do not consider the utility and low occupancy spaces.
- This experiment provides sampling for a maximum of 4 days only per season, this is due to cost of analysis, and the distribution of days will be determined by peak and low peak times.
- This experiment considers only 2 seasons as representational of the full variation of climatic conditions over a year.
- Meters used for this experiment provided CO2, RH, Temp. provided by CO2 meters.com See below the manufactured sensor limitations:
    - Measuring Principle: CO2, Non-dispersive infrared (NDIR) sensor
    - Measuring Range: 1% CO2 models 0-10,000 ppm; 30% CO2 models 0-300,000 ppm (0-30% vol.)
    - Repeatability: 1% CO2 models ±20 ppm, ±1% measured value; 30% CO2 models ±0.1%, ±2% of measured value
    - Accuracy: 1% CO2 models ±30ppm, ±3% measured value; 30% CO2 models ±0.2%, ±3% of measured value
    - CO2 Sensor Ratings: Life Expectancy >15 years; Warm-up Time <1 min (instant measurements)
    - Temperature Sensor: Range -40 to 120°C; Repeatability ±0.1°C; Accuracy ±0.5°C
    - Relative Humidity Sensor: Range 0-100%; Repeatability ±0.1%; Accuracy ±3%
    - Dimensions: L x W x D; (mm) inches; (146.1)5.75 x (91.4)3.60 x (32.7)1.30
    - Data Logging: Data Points 15,000 (CM-0016,-0017); 5,400 (CM-0018,-0018AA,-0019,
    - -0209,-0210); Programmable Interval Data Date, time, CO2, %RH, temp.
    - Power: Input Voltage 5VDC (use only supplied adapter); Power Consumption 500 mA (while charging); Charging Time 5-8 hrs. (approximately); Battery Type/Capacity 4xAA (CM-0016,-0017,-0018AA); Li-Ion Battery Lifetime 2-3 years depending on cycles

4.1.10. Research project objective

1. It is an accepted fact that indoor environments have the potential to harbour bacteria that are dangerous to human health (pending various factors for airborne and surface); it is an accepted fact that humans are the main source of pathogens in indoor environments (airborne and touch).
    a. To define the distribution of bacteria related to space use and design program.
    b. To understand the relationship of indoor environmental conditions and the persistence of harmful bacteria in indoor space.
2. To relate microbial risk to architectural design for future and existing design guidance. This investigation provides the first data on the South African microbial biome, and specifically in a high burden and transient patient healthcare environment.
3. To analytically compare spatial design layouts with the microbial load distribution and community diversity in both case study hospital sites.
4. To identify risk patterns in design planning (identify and establish universal environmental markers) through investigating microbial community and diversity distribution.

4.1.11. Value

As part of three experiments, the collated data of all experiment together provide potential value as described in the microbial experiment protocol Value chapter.
Furthermore this study provides data pertaining to building performance and design use.

4.1.12. References

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Chapter 5

5.1. Observational Study Experiment Proposal

5.1.1. Problem Statement

With partial reference to the Microbial Experimental Proposal document version 1:
"What benefit is there in studying the biome of an indoor environment? or..... Do we know the health impact of our planning and construction decisions on building users?
Both these questions are inherently the same question. We need to know the ecology of our indoor environment that we may know the impact of our design decisions. Studying the indoor biome, studying the human body and studying the methods of bacteria transmission provides tools for designers to relate human health to design planning and space creation.
We do not know what constitutes the indoor biome of any given indoor environment in South Africa, even less a Hospital and more specific an accident and emergency unit (a zone with high occupancy and through put of acutely ill people). Due to this fact one cannot relate the suggested design and

implemented ventilation strategy or the architectural planning program to the prevalence of certain bacteria organisms in that environment based on its occupancy load. The relationship with bacteria prevalence and architectural planning in user programs have not been studied, yet people are the single largest contributor to bacteria in indoor environments, making the indoor environment a conduit for pathogens.
The impact of airborne disease specifically TB and the co-relationship to HIV can be related to the conditions of indoor environments. The ventilation requirements and the methodology of space use play a fundamental role in the transmission of disease, not only airborne but also touch surfaces. "

The role of spatial design and functional room location relates to design and user program, which in turn directly impacts user interactions. These interactions could potentially be responsible for cross infectious conditions. When studying the science of bio-aerosol flow, pathways and aerosol transmission from person to person and space to space; the space use and layout contribute as a mitigating factor. Studying space use and function patterns in healthcare settings provides potential opportunities to mitigate airborne and other disease transmission pathways that are related to people and occupancy.
A 'real time' space use (function and flow) by observation and analysis can be utilised to understand and predict human interaction and space use by objective evidential means. A combined study of spatial observation with environmental data logging and microbial sampling could potentially provide tangible interrelationship correlations between risk, environment and space use.

5.1.2. **Experimental Hypothesis**

Observational experiment hypothesis:
Observational space analysis provides potential means to study human interaction and functional space use, programmed flow patterns and occupancy duration. Postulating that observational analysis can be utilised (considering disease transmission) with investigations of the static indoor environment conditions and the indoor microbial environment to proof the causal health impact of architectural design program and planning.

Related hypotheses...

Microbial experiment hypothesis: (Microbial experiment proposal version 1)
The study of the composition of the built environment indoor microbiome and the presence of pathogenic bacteria will provide evidence for co-relationships between the indoor environment conditions, occupancy and the architectural planning program. Postulating user health risks emanating from Architectural design planning.

Environmental experiment hypothesis: *Unremitting monitoring of indoor environmental conditions of the built environment provides potential data that can be correlated to occupancy patterns, functional space use patterns and sustainable conditions for the existence and persistence of microorganism. This study postulates that studying by continuous monitoring of CO2, Temperature and humidity one can provide data that can be attributed to occupancy increase or decrease (architectural planning efficacy and transmission risk), the presence and the persistence of pathogenic organisms (potential environments prone to transmission of disease by incubation)*

5.1.3. **Experiment**

1.5. Environment:

1. A&E and a hospital ward – Khyalitsha Hospital – Hospital A
2. A&E and a hospital ward - Mitchells plain Hospital – Hospital B

1.6. Pre observation test

Prior to the study observation a questionnaire will be circulated to the staff of the A&E and the selected hospital ward of each hospital to ascertain the peak patient load and venues, as well as personal perception with regards to personal safety and healthcare acquired infection. The purpose for this data is to determine the most appropriate four days of analysis for appropriate correlation with environmental data collection; as well as the personal perceived status quo of HAI. This questionnaire will only be distributed to hospital staff in the specified departments: Ward and Accident and Emergency unit.
Furthermore, a 'dry run' of the route will be conducted prior to the study which will enable the observers to familiarise themselves with the requirements and pathways.

1.7. Observational test Questionnaire

See table of questions (pg5) for pre observational test

No	QUESTION	RESPONSE						
Section A		Yes		Unsure		No		
1	Confirm if you are a hospital staff healthcare worker at this facility?							
2	In which department do you work?							
3	Do you feel safe in your work environment from acquiring airborne disease? (such as TB)							
3.1	If yes response to point 2 - Why?							
3.2	If no response to point 2 - Why?							
3.3	If unsure response to point 2 - Why?							
4	Do you feel that the surfaces in your department are sufficiently cleaned for infection and you are at no risk?							
4.1	If yes response to point 4 - Why?							
4.2	If no to response point 4 - Why?							
4.3	If unsure response to point 4 - Why?							
Section B		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
5	Which week days do you work?							
6	How long is your work shift?							
7	What time does you shift start and end?							

8	Which week days are busiest in you department							
9	Which week days are the quietest in your department							
10	What times of the day (of the full 24 hrs) do you perceive are the busiest during a busy day							
11	What times of the day (of the full 24 hrs) do you perceive are the busiest during a quiet day							
Section C								
12	Which rooms in your department do you perceive to have high activity spaces							
13	What is the total recorded number of patients in your department on a busy day (as stated in point 10) over 24 hours							
14	What is the total recorded number of patients in your department on a quiet day (as stated in point 11) over 24 hours							

5.1.4. **Area of investigation**

1. The study focuses on the emergency unit and a hospital ward of 2 hospitals in Cape Town. Preference is given to high travel zones with most through put of patients, HCW and staff.
2. A route map of the departments will be developed that will be followed and notations made in accordance with information required.

5.1.5. **Methodology**

The observation methodology used is based on University College London (UCL) Architecture Department, Space Syntax Software manuals. Extracted and compiled from: Space Syntax observational manual developed by Tad Grajewski, 1992 and updated by Laura Vaughan 2001 – UCL Space Syntax. A two task process is to be followed by observers over the period of a day for the study duration (4 days, 2 seasons). As previously indicated, a 12 hour period will be studied at each facility. A single observer will be required to observe for a total of 6 hours per day, thus 2 observers over a 12 hour period for each hospital, totalling 4 observers per day.
Notes: Due to the sensitive nature of the hospital environment care must be taken to ensure appropriate etiquette at all times: such as reporting to the ward nurse before study day commences, keep valid identification and a letter of authorisation and considering patients and their needs.

Observation task 1:
"Mental snap shot" Provide a floor plan at 1:50 scale (A3 Paper size) of the selected department. 'The power of this is that it makes the patterns of space use instantly apparent to a reader or client.

1. Map a route that will cover all rooms that are frequently used to ensure that all spaces (excluding storage areas) are observed (based on pre observation test and questionnaire).
2. Indicate any furniture and divisional change son the plan prior to commencing with the study. If a single space is to large the divide it into smaller zones that are individually assessed.
3. Walk this route once per hour, marking on the drawing in each space the number of people using a coding system.
    a. seated,
    b. standing,
    c. walking, (use an arrow indicting the direction) (do not count people behind you, or any one that enters the zone after your snapshot)
    d. talking,
    e. Dr
    f. Nurse
    g. Other
    h. Patient
    i. as well as the direction of their walking
    j. General occupancy number in the space at that moment in time.
4. Rooms that are locked or deny entry must be marked up with an X.
5. Do this for each room and passage along the route for the next hour, use a new, blank plan to repeat the route (thus for a single department, a total of 48 plans will be required for a 12-hour per day, 4 day observation).

Observation task 2:
"Movement tracer" This technique provides precise routes taken by people moving through space. When compiling this data with the mental snap shot technique one is able to determine use in the space and flow through the space.

1. Similar to task 1, spend 3-4 min in each of the rooms/spaces (4-5 min in the larger spaces – predetermined, and 3 min in smaller spaces – predetermined), marking movements of people entering or exiting the space on a blank floor plan indicated by flow lines.
2. Trace with a pen on the plan all the movement through the space, and conclude the flow line with an arrow where the person exists the space.
3. Define the space use: (using coloured opens to distinguish each one)
    a. Through
    b. To
    c. From
    d. within
4. Do this for each space on the same route map, twice every hour for the duration of the observation period. Use a blank floor plan for the 1st assessment and again a new blank plan for the final assessment.
5. This will be done twice per hour, once before Task 1 and again after Task 1.

5.1.6. **Observation Duration**

Observation will be done over a 4 day period (the specific days will be determined by the feedback on the questionnaire), this in turn will match the microbial sampling duration. The duration will be a total of twelve hours, over four days at each hospital. Constituting two six hour shifts by 2 observers per hospital.

5.1.7. **Analysis**

The collected data will be run through Depth map Space Syntax software _, this will provide graphical and percentage flow, use and occupancy over a longer period of time to determine the long term impact of the design program – Refer to Space Syntax Methodology manual, Depths map software: *Al_Sayed, K., Turner, A., Hillier, B., Iida, S., 2014 (2nd Edition), "Space Syntax Methodology", Bartlett School of Graduate Studies, UCL, London.*.
"Observations can be used to generate numerical data on space use and movement in urban areas and this data can be correlated with the spatial variables. The most important is between integration and encounters (observed use and movement). We can use the results of observation studies to research social variables: This is because integration is an independent measure - it is the integration value of a space that can produce the people (or the shops and other functional variable) but the presence of more people cannot make space more integrated." (Grajewski, Vaughan 2001)

Correlating the findings with environmental data and microbial data will determine the causal impact of more infected people in the 'said' environment. This enables prediction of transmission. In addition design variations will be run through the program to present the variation in the impact if architectural program and planning is altered. Utilising Space Syntax depthmap software (Al_Sayed et al. 2014), theoretical and quantitative model will be developed to define the space use and flow of each department. When combined with the static environmental data and the microbial sampling correlation between space use and occupant and organism prevalence can be deduced.

5.1.8. **Assistance**

1. 4x Technician/observers – (this is for both facilities) the technicians/observers will be given floor plans of each department with a marked out route. A drawing legend will indicate on the floor plan the required information. The floor plan will be marked up with annotations of: no of people in the space, seated, standing and direction of movement. This will be done once every hour for each department and the set zones as per plan will require a 3 min stop and observe and notate. This will occur for six consecutive hours per person per hospital per shift for four days.
2. Starting time of first shift: 06:00 am, shift change: 12:00am, last shift end: 18:00 pm.
3. Total time required per observer: 6hrs per day for 4 days Over two seasons: 48hrs total.
4. Total A3 printed 1:50 scale floor plans: 3 per hour (for each department) per observer per hospital: 36 floor plans per day per hospital, thus a total of 576 floor plans over 2 seasons

5.1.9. **Experimental Delineation**

1. This study only considers spatial observation data for the period of four days in two seasons as a representation of a an average seven day week over a calendar year
2. The observation period of twelve hours per day, observing on an hourly basis is assumed to represent the daily average usage pattern of the studied environment
3. This study observation are limited to the two selected hospitals: Khyalitsha Hospital & Mitchells plain Hospital and assumes to represent the average space use of high burdened healthcare facilities in South Africa.
4. This study accepts Space Syntax depth map software methodology (peer reviewed and used extensively) for modelling data as collected and appropriate for space use prediction and analysis.

5.1.10. **Research project Objectives**

The objectives of this observation experiments are to:

1) Provide evidence that user interaction is potentially causal of planning design.
2) Define the real time space use program, as this does differ from the initial devised design program.
3) To analytically compare spatial design layouts in both case study hospital sites. To identify user use and movement patterns to health risk in design planning (identify and establish universal environmental markers)
4) Correlate participants' diaries and CO2 data with spatial activity data, (an investigation proceeding in parallel with this investigation), see attached research proposal.
5) To relate both microbial and environmental data with the space use and occupancy,
6) Simply, by graphical means, present user activity of a given environment for further spatial analysis of design flow and space use that will be generated using depth map software

5.1.11. **Value**

As part of three experiments, this observational investigation forms a critical link in relating and identifying the human space use factor to microbial load and environmental conditions. The potential value that this investigation holds is stated in the microbial experiment protocol Value chapter.

Provides an analytical method to analyse space use and program in healthcare settings improving service delivery and potential HAI risk.

5.1.12. **References**

Al_Sayed, K., Turner, A., Hillier, B. & Iida, S. (eds) 2014, *"Space Syntax Methodology"
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RESEARCHER DECLARATION

APPLICATIONS MUST INCLUDE THE FOLLOWING STATEMENTS

Hereby I, ...Jako Albert Nice ..... in my capacity as.....Doctoral student researcher....., that

1 Research subjects will be informed, information will be handled confidentially, research subjects reserve the right to choose whether to participate and, where applicable, written permission will be obtained for the execution of the project (example of permission attached).

2 No conflict of interests or financial benefit, whether for the researcher, company or organisation, that could materially affect the outcome of the investigation or jeopardise the name of the university is foreseen.

3 Inspection of the experiments in loco may take place at any time by the committee or its proxy.

4 The information I furnish in the application is correct to the best of my knowledge and that I will abide by the stipulations of the committee as contained in the regulations.

5 Signed: _____ Date: _31 March 2015___

UNIVERSITY OF PRETORIA

FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

APPLICATION FOR APPROVAL OF A RESEARCH PROJECT

This application form must be read with the Regulations for Research Ethics and Integrity and completed. Important: Each item must be completed.

Date of submission	08 May 2015
1. DETAILS OF APPLICANT	
1.1 Applicant's surname	Nice
1.2 Applicant's initials	JA
1.3 Applicant's title (prof, dr, mr, ms, other)	Mr.
1.4 Postal address (where approval is to be sent)	Post net suite 112, box x19, Menlo Park, 0102
1.5 E-mail address	jnice@csir.co.za
1.6 Telephone	0736629547
1.7 School in Faculty (Engineering, Built Environment or Information Technology)	Built Environment
1.8 Department	Department of Architecture
1.9 Study leader/promotor (if the applicant is a student) name, address, e-mail address	Prof. Piet Vosloo Associate Professor, Department of Architecture Building Science, Room 2-16, University of Pretoria Email: piet.vosloo@up.ac.za
1.10 Names, addresses, e-mail addresses and capacity of co-researchers/ students/ lecturers involved with the project	Co-researchers: Co-researcher - Sonya Milonova, Pretoria/Boston, sonya.milonova@gmail.com (technical advisor) Co-researcher - Gingi Khoza, Pretoria, GKhoza@csir.co.za (student) Co-researcher - Tobias van Reenen, Pretoria, TvReenen@csir.co.za (technical advisor) Co-researcher - Kevin Bingham, Durban, kbingham@gmail.com (technical advisor)
2. RESEARCH PROJECT DETAILS	
2.1 Title of research project	Architecture, at a microbial nexus in Healthcare Acquired Infection; *A framework for an Architectural Design Microbial Risk Model (ADMRM)*

2.2 Furnish as brief outline the following so that the relevant ethical aspects can be identified clearly:

- Statement of the problem
- Statement of objectives
- Experimental methods/ measuring instruments
- Materials/Apparatus
- Profile of research subjects/target group/animals/environmental factors

See attached the relevant study experiments in PDF format, briefly detailing each experiment with the noted and requested aspect listed above.

1. PhD Environmental assessment experiment proposal protocol_JN 2015
2. PhD Microbial assessment experiment proposal protocol_JN 2015
3. PhD Observational assessment experiment proposal_JN 2015

PhD research proposal abridge version Ethics_Jako Nice 08_05_2015_

Further note: This research will be conducted simultaneously with another research project: Building airborne risk estimation - Occupant population re-breathed air fraction, in which the researcher is involved with and in association with UCT, DoH WC, and the same hospitals. That research project has been approved by all parties (Department of Health WC, UCT and both hospitals) see the attached document for your information. The intention is to link this research study with that project. Once ethic approval have been awarded for this study, a resubmission will be done for the other study to all the departments concerned (Department of Health WC, UCT and both hospitals) for a combined approval from all parties.

2.3 Is a research questionnaire/ survey/interview used? (Yes or No)	Yes
2.4 If yes, have you submitted this with your application? (Yes, No or Not Applicable)	Yes

3. RESEARCH SUBJECTS

If the project involves people, either individually or in groups, complete this section

3.1 Does the study involve people as informants, or does it involve people as research subjects? (Tick one)	Informants	Yes	Research subjects	No

3.2 Describe possible safety and health implications that participation in project may pose

There are no safety concerns, other than being present in a hospital health care environment such as any other public person. If required participants will have the option to wear N95 respirators to reduce the risk of contracting nosocomial disease as an when require per standard hospital protocol.

3.3 Expected duration of participation of subjects in the project	Total to maximum of consecutive four days in summer season and four days in winter season

3.4 Describe the manner in which confidential information will be handled and confidentiality assured

No manner of personal identification of interview participant will be collected. The period of sampling will run over various working shifts thus reduce possible risk of identification. The collected data (not questionnaire) does not refer to individuals but only number of people in an environment, and environmental conditions of that environment.
The identity of the hospitals if so required by the WC Department of health will not be disclosed unless otherwise stated.

3.5 Remuneration offered to subjects for participation	No remuneration will be provided to Hospital staff, remuneration will be provided to technicians/co researchers in assisting with data logging and administration

If the project involves animals, complete this section

3.6 Describe possible safety and health implications participation in the project may hold

3.7 Expected duration of participation by animals in the project	
3.8 Care/housing/feeding of the animals during the project	

4. ENVIRONMENTAL IMPACT

If the project may have a potentially detrimental environmental impact, complete the following

4.1 Potential impact on the environment	No impact, only static monitoring of CO2, temperature and humidity
4.2 Expected duration of the impact	
4.3 Locality of the project	Western Cape, Cape Flats – Mitchells plain hospital and Khyalitsha Hospital
4.4 Preventive measures	None required

5. DISSEMINATION OF DATA

Method of publishing/application of the results	For PhD thesis and journal paper publication as part of PhD requirements

6. SUBMISSION CHECKLIST

6.1 Have you submitted the Declaration by the Researcher? (See the website for this form)	Yes
6.2 Have you submitted an example of the informed consent form to be completed by each participant? (See the website for an example)	Yes

Built Environment
PO Box 395
Pretoria 0001
South Africa
Tel: +27 12 841 4985
Fax: +27 12 841 3539
Email: Nmatyila@csir.co.za

CONSENT FORM TO PARTICIPATE IN RESEARCH

An indoor microbial and environmental investigation to determine the extent to which occupancy patterns and space use in an urban South African hospital impact users.

You are asked to participate in a research study conducted by Jako Nice (MArch), Gingi Khoza,Toby van Reenen, Sonya Milonova (MSc), Kevin Bingham (MArch), from the Built Environment Unit at the CSIR, and Fogarty research Grant Fellows. The results of the study will contribute to a Doctoral thesis under the University of Pretoria, Department of Architecture.

You were selected as a possible participant in this study because you are a medical staff member working in the Accident Emergency department under investigation and are in a position to comment on your experience of the patient and user flow patterns in this department.

1. PURPOSE OF THE STUDY

The purpose of the study is to determine the relationship to sampled microbiota and identification of certain organism in this hospital and the user flow and occupancy patterns as they relate to the architectural design layouts. Your hospital was issued the same brief as another hospital but the architectural design of each varies considerably.

The outcome will contribute towards the development of a microbial design guide for architects and built environment specialist to improve the potential infection risk by HAI for both retrofit and new hospitals in building design..

2. PROCEDURES

If you volunteer to participate in this study, we would ask the following of you:

1. Permission to mount data loggers that will collect temperature, humidity and CO2 in the room. And your permission to place an air sampler that will suck air onto a filter and collect organism and dust from the air twice a day for a maximum of 30 minutes at a time, and plates on surfaces twice a day for a total of 30 minutes each time.

   The data logger device is about the size of a cell phone and will record for 96 hour period in two seasons. This device cannot make audio recordings so no confidential conversation can be recorded. The plates are small circular Petri dishes with agar in, and the air sampler is an mechanical machine placed in the center of a room for a short time to collect Bioaerosol particles.

2. Permission for a research investigator to be present during the day from 06:00 – 18:00 in the department as unobtrusive as possible, doing hourly rounds on a fixed route: observing people using the room and counting the number of staff, patients and visitors in each room on the path.

   The purpose of the investigation is define how your department is used and how many people occupy the department over various times in the day. This person will be respectful of your right to dignity and privacy and will undertake to remain as unobtrusive as possible and will not engage with you, except to administer the questionnaire.

3. Permission for a short questionnaire to be administered regarding your perception of environment for. The investigator will issue and collect the questionnaire and be available to explain it to you if necessary. This will be have three sections as follows:

   Section A your perceptions on the infection control risk in your environment

   Section B and **Section C** is about your work schedule and the number of people in your environment.

3. POTENTIAL RISKS AND DISCOMFORTS

There is potential that the presence of the research investigator may cause you to feel uncomfortable. However, the investigator is under instruction to avoid engaging with you and is to remain quiet and out of the way of normal hospital activity. The only time that the investigator is to engage with you will be to administer the questionnaire twice a day.

A number of investigators, named above, will take turns to change batteries of equipment, check recorded levels, place and collect microbial samples and take notes on an hourly walk through route that will remain the same route throughout the study, there may be a slight disturbance hourly as they make their walk through and once.

The investigator may be requested to leave the ward room for a period if sensitive activities or procedures are taking place.

4. POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

You, the participant, will not benefit directly or immediately from this investigation.

The potential benefit to science is to gain a better understanding of the microbial communities that exist in the South African indoor environment and the role architecture and programming plays in order to improve hospital environments in the future, to the benefit of both patients and staff.

5. PAYMENT FOR PARTICIPATION

You, the participant, will not receive payment for participation.

6. CONFIDENTIALITY

No confidential information is required for this study.

If any confidential information is accidentally obtained (over-heard by the investigator) it will not be recorded or reflected in the study and will remain confidential.

The data collected will be captured and stored electronically in a password protected domain that will only be accessible to the principle investigator.

The data collected from this study will be released to the University of Pretoria Statistics Department for statistical analysis.

The findings of this study will be published in both the doctoral thesis and scientific journals, however, the hospital and participants will not be disclosed in any publication.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact:

Principal Investigator: Jako Nice – 0736629547, jnice@csir.co.za

Supervisor: Prof Piet Vosloo – 012 420 4128, piet.vosloo@up.ac.za

Co-investigators: Tobias van Reenen – TvReenen@csir.co.za

Claire du Trevou – claire.dutrevou@gmail.com

Sonya Milonova - sonya.milonova@gmail.com

Faatiema Salie - faatiema@gmail.com

Carl Morrow - Carl.Morrow@hiv-research.org.za

Kevin Bingham - kbingham@gmail.com

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Dr Sandile Ncanana, the CSIR REC Secretariat, [R&DEthics@csir.co.za/012 841 4060] at the Research and Development Office.

Signature of research participant or representative in cases where a participant is uncomfortable with writing

The information above was described to [*me/the participant*]

by _____ [*name of relevant person*] in_____ [*Specify the language]* and [*I am/the participant is*] in command of this language or it was satisfactorily translated to [*me/him/her*]. [*I/the participant*] was given the opportunity to ask questions and these questions were answered to [*my/his/her*] satisfaction.

[*I hereby consent voluntarily to participate in this study/I hereby consent that the subject/participant may participate in this study*] I have been given a copy of this form.

_____	_____	_____
Name of Participant	**Date**	**Signature**
_____	_____	_____
Name of Representative (If applicable)	**Date**	**Signature**

Signature of investigator/interviewer

I _____[*name of the interviewer*] declare that I explained the information given in this document to _____ [*name of the participant*] and/or [*his/her*] representative _____ [*name of the representative*]. [*H*e/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in _____ [*state the language used*]. There was no need for a translator since the participant understood the language used above or this conversation was translated into _____ [*state the language*] by _____

_____	_____
Signature of Investigator/Interviewer	**Date**

	Research Questionnaire **An indoor microbial and environmental investigation to determine the extent to which occupancy patterns and space use in an urban South African hospital impact users**	**South Africa, Western Cape, 2015** **Accident & Emergency department** **Facility** **Date** **Time** **Facility**

No	QUESTION	RESPONSE		
	Section A	**Yes**	**Unsure**	**No**
1	Confirm if you are a hospital staff healthcare worker at this facility?			
2	In which department do you work?			
3	Do you feel safe in your work environment from acquiring airborne disease? (such as TB)			
3.1	If yes response to point 2 - Why?			
3.2	If no response to point 2 - Why?			
3.3	If unsure response to point 2 - Why?			
4	Do you feel that the surfaces in your department are sufficiently cleaned for infection and you are at no risk?			
4.1	If yes response to point 4 - Why?			
4.2	If no to response point 4 - Why?			
4.3	If unsure response to point 4 - Why?			

Section B		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
5	Which week days do you work?							
6	How long is your work shift?							
7	What time does you shift start and end?							
8	Which week days are busiest in you department							
9	Which week days are the quietest in your department							
10	What times of the day (of the full 24 hrs) do you perceive are the busiest during a busy day							
11	What times of the day (of the full 24 hrs) do you perceive are the busiest during a quiet day							
Section C								
12	Which rooms in your department do you perceive to be high activity spaces							
13	What is the average total recorded number of patients in your department on a busy day (as stated in point 10) over 24 hours							
14	What is the average total recorded number of patients in your department on a quiet day (as stated in point 11) over 24 hours							

Western Cape Government
Health

STRATEGY & HEALTH SUPPORT
Health.Research@westerncape.gov.za
tel: +27 21 483 6857: fax: +27 21 483 9895
5th Floor, Norton Rose House,, 8 Riebeek Street, Cape Town, 8001
www.capegateway.gov.za)

REFERENCE: WC_2015RP51_445
ENQUIRIES: Ms Charlene Roderick

Private Bag X20
Hatfield
Pretoria
0028

For attention: **Mr Jako Nice, Dr Piet Vosloo, Dr Don Cowan, Ms Gingi Khoza, Mr Kevin Bingham and Mrs Peta De Jager**

Re: ARCHITECTURE, AT A MICROBIAL NEXUS IN HEALTHCARE ACQUIRED INFECTION; A FRAMEWORK FOR AN ARCHITECTURAL DESIGN MICROBIAL RISK MODEL (ADMRM).

Thank you for submitting your proposal to undertake the above-mentioned study. We are pleased to inform you that the department has granted you approval for your research.
Please contact the following people to assist you with any further enquiries in accessing the following sites:

Khayelitsha Hospital **A Kharwa** **Contact No: 021 360 4227**

Kindly ensure that the following are adhered to:

1. Arrangements can be made with managers, providing that normal activities at requested facilities are not interrupted.
2. Researchers, in accessing provincial health facilities, are expressing consent to provide the department with an electronic copy of the final feedback (annexure 9) within six months of completion of research. This can be submitted to the provincial Research Co-ordinator (Health.Research@westerncape.gov.za)

3. The reference number above should be quoted in all future correspondence.

Yours sincerely

AS HAWKRIDGE

DR A HAWKRIDGE
DIRECTOR: HEALTH IMPACT ASSESSMENT
DATE: 3/12/2015.
CC **M PHILLIPS**

DIRECTOR: EASTERN/ KHAYELITSHA

Western Cape Government
Health

STRATEGY & HEALTH SUPPORT
Health.Research@westerncape.gov.za
tel: +27 21 483 6857: fax: +27 21 483 9895
5th Floor, Norton Rose House,, 8 Riebeek Street, Cape Town, 8001
www.capegateway.gov.za)

REFERENCE: WC_2015RP51_445
ENQUIRIES: Ms Charlene Roderick

Postal Address
Private Bag X20
Hatfield
Pretoria
0028

For attention: **Mr Jako Nice, Dr Piet Vosloo, Dr Don Cowan, Ms Gingi Khoza, Mr Kevin Bingham and Mrs Peta De Jager**

Re: ARCHITECTURE, AT A MICROBIAL NEXUS IN HEALTHCARE ACQUIRED INFECTION; A FRAMEWORK FOR AN ARCHITECTURAL DESIGN MICROBIAL RISK MODEL (ADMRM)

Thank you for submitting your proposal to undertake the above-mentioned study. We are pleased to inform you that the department has granted you approval for your research.
Please contact the following people to assist you with any further enquiries in accessing the following sites:

Mitchells Plain Hospital **H Human** **Contact No: 021 377 4306**

Kindly ensure that the following are adhered to:

1. Arrangements can be made with managers, providing that normal activities at requested facilities are not interrupted.
2. Researchers, in accessing provincial health facilities, are expressing consent to provide the department with an electronic copy of the final feedback (annexure 9) within six months of completion of research. This can be submitted to the provincial Research Co-ordinator (Health.Research@westerncape.gov.za)

3. The reference number above should be quoted in all future correspondence.

Yours sincerely

A HAWKRIDGE.

DR A HAWKRIDGE
DIRECTOR: HEALTH IMPACT ASSESSMENT
DATE: 1/12/2015.
CC P OLCKERS **DIRECTOR: KLIPFONATIN/ MITCHELLS PALIN**

UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

FACULTY OF HEALTH SCIENCES
Human Research Ethics Committee

Form FHS007: Amendment – study staff

HREC office use only (FWA00001637; IRB00001938)			
☑ Approved			
This serves as notification that all changes to the study staff and documentation described below are approved.			
Chairperson of the HREC signature		Date	17/7/15.

Principal Investigator to complete the following:

1. Protocol information

Date (when submitting this form)	15 July 2015
HREC REF Number	239/2015
Protocol title	Building airborne risk estimation – Occupant population re-breathed air fraction.
Protocol number (if applicable)	N/A
Principal Investigator	Dr. Carl Morrow
Department / Office Internal Mail Address	Desmond Tutu HIV Center, N1,21, Wernher Beit North Building, Faculty of Health Sciences

1.1 Does this protocol receive US Federal funding?	■ Yes	☐ No

2. Items for approval

Please list on the page below all staff changes and additional documentation such as CVs and revised consent forms which need approval. This information must correspond to all 'yes' answers below. This page will be detached, signed and returned to the PI as notification of approval. Please add extra pages if necessary.

3. List of documentation (eg: CVs, Declarations & GCP Certificates)

1. Cover Letter
2. University of Pretoria Faculty Committee for Research Ethics and Integrity Approval Letter
3. Hospital Consent Form
4. Hospital Invitation (A) Khayalitsha, (B) Mitchells Plain
5. PhD proposal
6. Researcher Declaration

4. Staff changes (tick ✓)

Are new personnel being added to this research?	■ Yes	☐ No
Are current personnel being removed from this research?	☐ Yes	■ No
Is the principal investigator for this research being changed? If yes, please attach revised conflict of interest and PI declaration statements. (Refer: sections 7 and 8.4 in the New Protocol Application Form)	☐ Yes	■ No
Do the consent and assent forms need modification to reflect these staff changes? If yes, please attach copies of the revised forms, with all changes highlighted or tracked.	☐ Yes	■ No

5. Signature

My signature certifies that I will maintain the anonymity and/ or confidentiality of information collected in this research. If at any time I want to share or re-use the information for purposes other than those disclosed in the original approval, I will seek further approval from the HREC			
Signature of PI		Date	15 July 2015

Ph.D. Research Proposal Ethics – protocol

Doctoral Program in the Faculty of Engineering, Built Environment &IT

Department of Architecture

Title (new)

Architecture, at a microbial nexus in Healthcare Acquired Infection;
A framework for an Architectural Design Microbial Risk Model (ADMRM)

Candidate
Jako Albert Nice
jnice@csir.co.za

Supervisor
Professor Piet Vosloo
University Pretoria

Version: Protocol _ 13 July 2015

Department of Architecture
Faculty of Engineering, Built Environment & IT
UNIVERSITY OF PRETORIA

Abbreviations

Abbreviation	Full wording
IAQ	Indoor Air Quality (related to pathogens)
ISQ	Indoor Surface Quality (related to pathogens)
HAI	Healthcare Associated Infection
MB	Microbial Burden
CFU	Colony Forming Units
ABC	Airborne Bacteria Count
SBS	Sick Building Syndrome
BRI	Building Related Illness
CEMS	Carbon Dioxide Evolution Monitoring System
BE	Built Environment
HVAC	Heating Ventilation and Cooling
CFD	Computational Fluid Dynamics
BIM	Building Information Modelling
SEM	Scanning Electron Microscopy
NP	Nano Particles
UVGI	Ultraviolet Germicidal Irradiation
CU	Copper
PVC	Polyvinyl chloride
HAP	Hospital associated pathogens

Abbreviation	Full wording
EA	Enterobacter Aerogenes (EA)
CRPA	Carbapenum-Resistant Pseudomonas Aeroginosa (CRPA)
MRSA	Methicillin-Resistant Staphylococcus Aureus (MRSA)
VRE	Vancomycin-Resistant Enterococcus (VRE),
TB	Tuberculosis
HIV&AIDS	Human Immunodeficiency Virus Infection & Acquired Immunodeficiency Syndrome
CRE	Carbapenem resistant enterobacteriaceae - strain-E. coli,
PA	Pseudomonas aeruginosa

Terms

Biofilm
Phenotype
Intracellular
Extracellular
Gram stain
16SrRNA
Aerobic
Anaerobic
Ecology
Micro Biome
Ion
Ionisation
Fall – out
Electrostatic
Particle charge
Space Syntax

Chapter 1

1.1. Introduction and Background

Built Environment microbiomes, Healthcare Acquired Infection (HAI) and Hospital Associated Pathogens (HAP)

The impact of the built environment on occupational comfort and wellbeing have been widely documented within the field of architecture. Margaret Campbell in her paper: '*What Tuberculosis did for Modernism: The influence of a Curative Environment on Modernist Design Architecture' (Campbell 2005)* mentions a few of the direct impacts that architecture have on the built environment and the wellbeing and health of people over the past 150 years. Looking at the rate of urbanisation and city densification, the indoor environment is becoming a greater source for health concern. Much research has been done across the world in various social settings and climatic conditions investigating healthcare associated infection (HAI) or medically termed nosocomial infection (Ducel et al. 2002) . The research outcomes point to the hospital built form being the transmitter and possible incubator of bacteria that causes various illnesses through infection.

This thesis investigates the hospital environment in an attempt to hypothesise towards the greater built environment; in order to understand and model the reservoir formation and pathogen transmission.

The way we interact in living spaces, the way that we air-seal living spaces, the way that we ventilate and clean living spaces and the material and methods we use to construct living spaces - all play fundamental parts - in the microbial make-up that architecture either advertently or in inadvertently cultivates. The postulated result: Nosocomial infection or HAI.
The spread of infectious bacteria, fungi, viruses and single cell organisms (prokaryotic & eukaryotic) specifically in hospitals are widely known to be first by human contamination (Hospodsky et al. 2012) and secondly environmental condition dependant (Eshun-Wilson et al. 2008, Basu. et al. 2007, Wolfaardt et al. 2010) etc. Therefor the presence of specific pathogenic harmful microbes that either survives and possibly proliferates in the built environment; or cultivated in humans and by interaction distributed and cross-infected to other humans, are deposited and even incubated in these environments. Given that favourable environmental conditions are provided. Hospital Associated Infection (HAI) is prevalent worldwide in health care facilities. South Africa and sub Saharan Africa with the epidemic of the human immunodeficiency virus infection & acquired immunodeficiency syndrome (HIV&AIDS) face a tougher immune deficiency challenge in the form of *tuberculosis (TB).*
Current research indicates that we might have overlooked a key area in the response to non-tuberculosis bacteria (NTB), TB and other invasive pathogenic microbes; the very microbial environment in which bacteria survives, live, are aerosolised and surfaced in. Conclusive research is required to indicate the effect and survival from aerosol to surfaces and *vice versa*.
The architectural concept: Space Syntax developed by Bill Hillier, Julienne Hanson, Philip Steadman and colleagues at The Bartlett University College London assesses spatial use based on function, user behaviour and distribution to provide a platform for evidence based research design. This model was developed for urban planning but has evolved to internal space relationship design development such as hospitals etc. (Dursun 2007, March 2002). The approach creates opportunities to model possible risk and design that considers life cycle analysis of ecosystems in Hospital environments.

The primary focus of Indoor Air Quality (IAQ) and risk has been either airborne or surface; however there exist yet another environment, the space in between these two spheres. This phenomenon is seen in the use of copper as an anti-microbial agent. A 'halo' of unknown diameter and form, related to the purity and quantity of copper has been found in sampling adjacent non Cu materials. This results in prevention of microbial growth, proliferation and formation, as is evident in the reduction of colony forming unit (CFU) count (Karpanen et al. 2012). The author presents a peer review and presented paper in the annexure on the need and lack of current research in defining the characteristics of this halo zone and even the measurability of the "ion" halo. The existence of this zone presents intriguing opportunities for study and unlocks a new area of investigation with regards to architecture, environmental risk and the use and role of materials. This thesis will investigate these possibilities.

Background to rational

Mycobacterium tuberculosis (M.Tb) is the bacterium that causes TB. TB is source based, hence only a person that produces M.Tb can transmit TB. Being of obligate airborne infection nature, people with TB disease release M.Tb through aerosols produced by coughing called droplet nuclei. The inhalation of M.Tb droplet nuclei spreads TB. Tuberculosis is clinically categorised as TB infection, TB transmission or TB disease.
TB disease can be inactive with the presence of M.Tb bacilli due to a healthy immune system. They can however become active if in contact with other infectious people increasing the number of droplet nuclei. This state of TB IS also known as latent TB infection (LTBI). One in ten people develop TB diseases that have LTTB infection (Bock et al. 2007). TB disease occurs predominantly in the lungs and a person with TB disease may be an active M.Tb producer. It can however also manifest as meningitis and in organs, IRIS, spine etc. There are differing strains of TB, relative to their drug resistance, they are categorised as M.Tb, multi drug resistant (Mdr) TB and extensively drug resistant (Xdr) TB and recently Total drug resistant (Tdx), Tdx and Xdr TB strains being the most concerning.

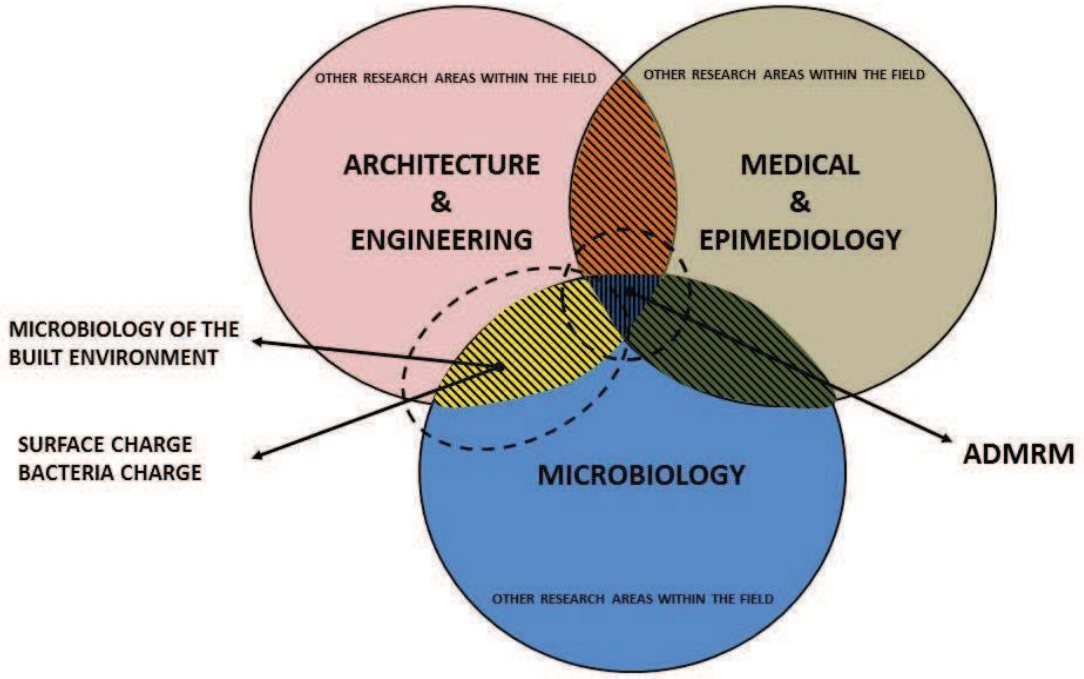
It is evident that TB is a global problem and an epidemic in South Africa. The nature of TB infection by airborne makes all actively infected, latent infected Ill people with an immune deficiency disease i.e. HIV, unsuspected patients, health workers or healthy people all potential victims of TB. Studies seem to indicated that health care facilities are contributing to the spread of TB bacteria (Eshun-Wilson et al. 2008) South Africa is ranked the worst infected country in the world (per capita) of *Mycobacterium tuberculosis* (WHO. 2009a). As far as Mdr and Xdr TB are concerned *"South Africa is the third highest tuberculosis burden country in the world, lagging behind two countries, China and India, who have significantly larger populations than ours"* (Motsoaledi, Norbert 2011). The epidemiological burden of TB and HIV co-infection in South Africa is estimated at 70% + (WHO. 2009a). The growth of drug resistant strains of TB, compounds the heavy burden of TB in South Africa. Numerous organisations such as: World Health Organisation (WHO), Centre for Disease Control (CDC), Council for Scientific and Industrial Research (CSIR) etc. in partnership with the South African National Department of Health are contributing to address the epidemic facing South Africa and other parts of the world. In South Africa out of every 100 000 people, 768 are TB positive (WHO. 2011). The unconfirmed cases might well be far in excess and of those confirmed cases 70% (as noted above) have HIV Aids. It must be notes that more than 5.5 million people in South Africa have HIV Aids and are thus highly susceptible to TB due to the immune co-relationship that these diseases share. These statistics points to the exposure and the unsuspecting healthy people, patients in hospital environments and public settings. The rate of incidence and prevalence locally are still on the increase, however the growth rate is positive and reflect a slow decline annually (WHO. 2013). With little research in building design, social anthropology and financial backing this epidemic of TB will continue to impact the lives of millions locally and globally.

The WHO has recently done a study within the South-East Asia, Europe, Eastern Mediterranean and Western Pacific areas (2009). The outcome reflected that "8.7% of hospitalised patients suffer health care associated infection". The study concluded that worldwide up to "1.4 million people suffer from infectious complication acquired in Hospitals" (WHO. 2008). "In South Africa TB has become a driver in nosocomial infection. One such case study: The "Tugela Ferry TB outbreak in 2005-2006" recorded 8 deaths of hospital staff as a conclusive result of nosocomial infection. "Hospital transmission was a major factor" (Koenig 2008)
"There is growing evidence that institutional transmission is a critical factor in epidemic HIV-associated TB and MDR-TB. Infection prevention and control (IPC) is only now becoming a feature of the global strategy to control TB. In South Africa, IPC remains the responsibility of individual healthcare facilities. There is an urgent need to obtain data on nosocomial transmission" (Sissolak, Bamford & Methar 2010). Studies have been done by staff at Tygerberg Academic Hospital among their own staff to ascertain the impact of nosocomial infection (Eshun-Wilson et al. 2008). The studies were done over an 11 year period and the infections totalled over 130 health care worker infections. Similar studies in Kwa-Zulu- Natal by (Naidoo, Jinhabhai 2006) over the period of 5 years, 1999-2004 indicated "1133 per 100 000 health care workers" (HCW) were infected by TB (Naidoo, Jinhabhai 2006) Similar studies that have been conducted globally all point to the same concern, nosocomial infection has major implications on the most precious health resource South Africa and other countries have: the health care worker.

Background to rational Continued

This section is still to be completed with all relevant paper reference evidences.
The increase in hospital acquired infections (HAI) in hospitals (Eames. et al. 2009) and the cost burden on government is immense. This has been quantified in various countries globally (Klevens et al. 2007b, Mendell. et al. 2002) but not in South Africa, due to the burden of disease and levels of poverty (Motsoaledi, Norbert 2011, WHO. 2009b, Koenig 2008), it is likely to be far in excess of the some international statistics per capita. It not only impacts financially but it also impacts the general health condition of communities (Murray. 2004). In the current era of HIV and TB in South Africa the impact of immune compromised patients by HAI is deadly (Marais et al. 2006, Nyamogoba et al. 2012, Fennelly 2007), it only worsens the fight against these diseases (Koenig 2008). South Africa is not limited by the two major disease burdens of HIV and TB, but also others impact the immune compromised individuals. As indicated in the table below. Mendell et al. communicates the current state of the United States health cost condition: 'Available data suggest that improving building environments may result in health benefits for more than 15 million of the 89 million US indoor workers, with estimated economic benefits of $5 to $75 billion annually. (Mendell. et al. 2002). The following statistics reflect estimated USA cost burdens and economic impact in 2002: ten billion dollar annual health care cost, nineteen billion dollar annual work absence cost, three billion dollar annual reduced performance loss cost. (Mendell. et al. 2002).
This represents an alarming cost to government condition, fuelled by HAI, it is evident that both surface and air plays a defining role in the health and wellbeing of patients and visitors. And hence good Indoor Air Quality (IAQ) and Indoor Surface Quality (ISQ) are required to reduce the above mentioned costs and improve environmental conditions.

Built environment micro biomes – 'Bio-informed design'



A field of study that has been developing in recent time sheds a new perspective on the built environment: The microbial environment. Architects and engineers without conscious consideration have been designing these environments for centuries. The "microbial landscape" or "built environment micro-biome" are under research by amongst others, ecologist Jessica Green and fellow researchers from the University of Oregon and the Santa Fe Institute. To quote from a recent paper presented by this team of researchers:
'Just as we currently manage natural ecosystems to promote the growth of certain species and inhibit the growth of others, an evidence-based understanding of the ecology of the built environment microbiome opens the possibility that we can similarly manage indoor environments, altering through building design and operation the pool of species that potentially colonize the human micro- biome during our time indoors' (Kembel et al. 2013).

In March 2014 the American Association for the Advancement of Science (AAAS) held a symposium in Washington DC, USA to bring light to this fast growing research subject to involve leading researchers to contribute to this think-tank. Currently this field of research is driven by three major organisation/institutions with funding from either Sloan foundation or the American Government. Organisations involved are: BioBE – Jessica Green and colleagues (Oregon state University), Hospital Biome project (interdisciplinary team of researchers), microBEnet site and research driven by Jonatham Eisen at UCL Berkley and Hal Levin, with other research parties in Toronto Canada: Jeffrey Siegel at Toronto University. This research also connects with the Human biome research project that has been running for some years. The most current think-tank is to take place in Hong Kong, at the ISAQ – Indoor Air conference and Sloan symposium on the built environment.

The built environment is host to vast variety and quantity of mycobacteria. The human spends most of his time - nearly 85% - within these environments. Over time we have adapted and engineered these environments so suite our comfort and our needs. What we have neglected to consider are the environments invisible to the naked eye that we have created which impact on our health (Hospodsky et al. 2012, Rintala et al. 2008). Similar to the deductions that Margaret Campbell has made (Campbell 2005), researchers from the Environmental Health Department, National Public Health Institute in Helsinki, Finland have begun quantifying and defining these facts in their paper: '*Diversity and seasonal dynamics of bacterial community in indoor environment.'* (Rintala et al. 2008).
Biomes: _ *'as for any other biome, the composition of the built environment micro biome is determined by some combination of two simultaneous ecological processes: the dispersal of microbes from a pool of available species and selection of certain microbial types by the environment* (Kembel et al. 2013).
Man has created environments that consequently become the production of human pathogenic microbes by cancelling out 'competitive exclusion' through the various methods of sterilisation. The result is removing the later part of the ecosystem, but forgetting that he himself is the host to the most harmful pathogens. Architecture and the microbial environment are not separated, but in fact intimately fused.
Can one combine current architectural research in space syntax with environmental risk and microbial growth knowledge and theory as design tools towards developing real world health guidelines in building design?

This thesis postulates the possibility to develop a dynamic tool that incorporates space syntax, risk models (sampling and theoretical) for surface and airborne contagion and microbial interaction that could generate an architectural theory and system of design that can be used for validation and guidance towards a health conscience design.

The following is a preliminary abstract of interdisciplinary paper collaboration by the author – an architect and a microbiologist Phd candidate researcher in Toronto Canada. It discusses and explores the research, focus and purpose for the built environment microbiome; the data and concept will be used to develop the microbial theory for design in the architectural microbial model:

Built form surfaces as culture source for biofilm hosting, causative of Hospital Acquired Infection, however likewise a potential source for competitive Environmental Mycobacteria.

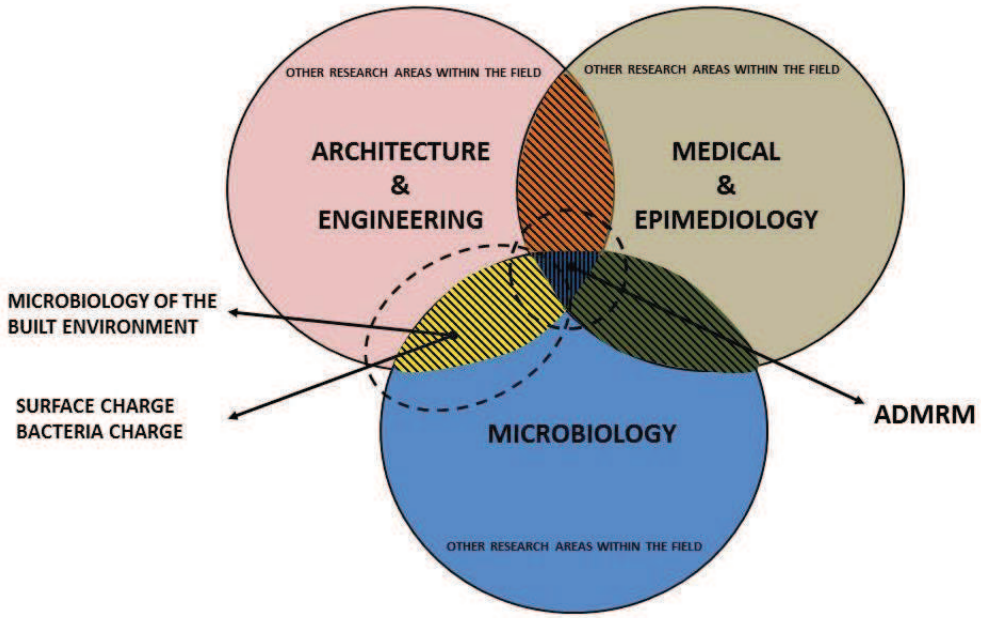
The increase in hospital acquired infections (HAI) in hospitals (Eames. et al. 2009) and the cost burden on government is immense, this has been quantified internationally (Klevens et al. 2007b, Mendell. et al. 2002) but not in South Africa, due to the our burden of disease and levels of poverty (Motsoaledi, Norbert 2011, WHO. 2009b, Koenig 2008), it is likely to be far in excess of the some international statistics per capita. It not only impacts financially but it also impacts the general health condition of communities (Murray. 2004). In the current era of HIV and TB in South Africa the impact of immune compromised patients by HAI is deadly (Marais et al. 2006, Nyamogoba et al. 2012, Fennelly 2007), it only worsens the fight against these diseases (Koenig 2008). South Africa is not limited by the two major disease burdens of HIV and TB, but other that prey on immune compromised individuals. Some of these noted for this study are: NTB/NTM - Pseudomonas Aeruginosa, Staphylococcus aureus, Acinetobacter baumannii, M. fortuitum, M. chelonae, M. abscessus; Legionella, Protozoa, Pneumocystis jiroveci Pneumonia etc. (Morris, Harrison 2003, Nseir et al. 2002, Taylor, Ross & Bentham 2009, Nevez et al. 2008) Literature refers Pneumocystis jiroveci Pneumonia the most common and bacterial infection. It must be noted, that this list contains both bacterial and fungal (spore) species. Each of these species poses a health threat to an unsuspecting visitor or patient, and more critical an immune suppressed patient or undiagnosed TB patient.

In a paper written by Kremer, Schewebke & Kampf: How long do nosocomial pathogens persist on inanimate surfaces? A systemic review (kremer, Schewebke & Kampf 2006). A systematic literature review was conducted on the persistence pathogen survival on surface, however some of the reference data are outdated and needs to be substituted with more recent studies. It nevertheless communicates the importance of understanding the microbial environment and its role as incubator. Wolfaardt in a paper: Integration and proliferation of Pseudomonas aeruginosa PA01 in multispecies biofilm (Wolfaardt. et al. draft), describes this survival and dispersal methods of pathogens using Pseudomonas aeruginosa as sample type.
This requires architects and designers, engineers, construction managers and policy makers to understand the interaction between organisms and the built environment, the inhibition and or proliferation of pathogens. There is a notable difference between Lab culturing theory and wild type culture: practical site testing and experimentation. A large portion of the current microbiological theory we know originates from lab cultures and does pose questions as to the "reality" relationship with a much wider variety of environmental impacts and considerations. It is most appropriate for understanding behaviour but it is time that multi-disciplinary teams get involved in site based /wild type analysis and exploration.
The understanding of pathogenesis, the presence and formation of biofilm appears to be the critical question. Can species co depend and thus manage to survive in high stress environments such as hospitals (Wolfaardt. et al. draft, Taylor, Ross & Bentham 2009) The nature of biofilm survival and the persistence on material types and environmental conditions needs further in depth research, various researchers have initiated this investigation (kremer, Schewebke & Kampf 2006, Kolter, Siegele & Tormo 1993, Kolter, Greenberg 2006, Ronan et al. 2013)

The possibility and methodology of bacterial communication: quorum sensing is discussed by De Kievit, Kolter and other (De Kievit, Iglewski 2000, Kolter, Siegele & Tormo 1993) this fascinating discovery asks a striking question to the Architect, engineer and policy maker: Do we create environments by our choices of material, ventilation systems, spatial layouts and simulated environmental conditions that stimulate the "activators" or "receptors" that trigger communication sensing between bacteria (Kolter 2010, Claesson 2010); in so doing cause them to either proliferate or go into a desiccate state of survival. Various studies indicate this behaviour of microbes under certain stress conditions; we need to compare these conditions to our built environment. (Parsek, Fuqua 2004, Ronan et al. 2013). Researchers De Boer et. Al. in their study for Pneumonia outbreaks in renal patients has published a paper: An outbreak of Pneumocystis jiroveci Pneumonia with 1 predominant Genotype among Renal Transplant Recipients: Inter human Transmission or a Common Environmental source.

In understanding this communication, survival, proliferation of bacteria one can now postulate beyond the known: Do probiotic walls, non-sterile walls and surface promote or inhibit the persistence of bacteria. Which elements in the material surface benefit or inhibit the growth, which sources activates the sensors for colony formation or deactivation further cultivation; these are critical architectural considerations and questions for public health.
To investigate these questions a multi-disciplinary team consisting of both an architect and microbiologist pose some explorative questions for experimentation: Dry biofilm experimentation, the condition of high desiccate biofilm formation a similarity to inanimate surfaces in environments such as hospitals. PhD candidate Wendy Stone proposes a Carbon dioxide evolution monitoring system (CEMS) experiment to evaluate biofilm life activity on the basis of CO2 measurements; this will be done for various HAI bacteria. It will be tracking the metabolic rate and thus evaluate the life activity of the bacteria/biofilm.

Now if one evaluates these finding with regards to other surface types it will allude to the specification of surfaces that either prevent growth, the cleaning of surface to reduce growth and nutrient intake or the probiotic surface that promotes growth in the sense of outcompeting with another non-pathogenic bacteria such as Bbellovibrio bacteiovorus (Chang. et al. 2011). If these organism do survive, what is the method of survival and feeding, Experimentation will allow us to systematically define the source and origin of their

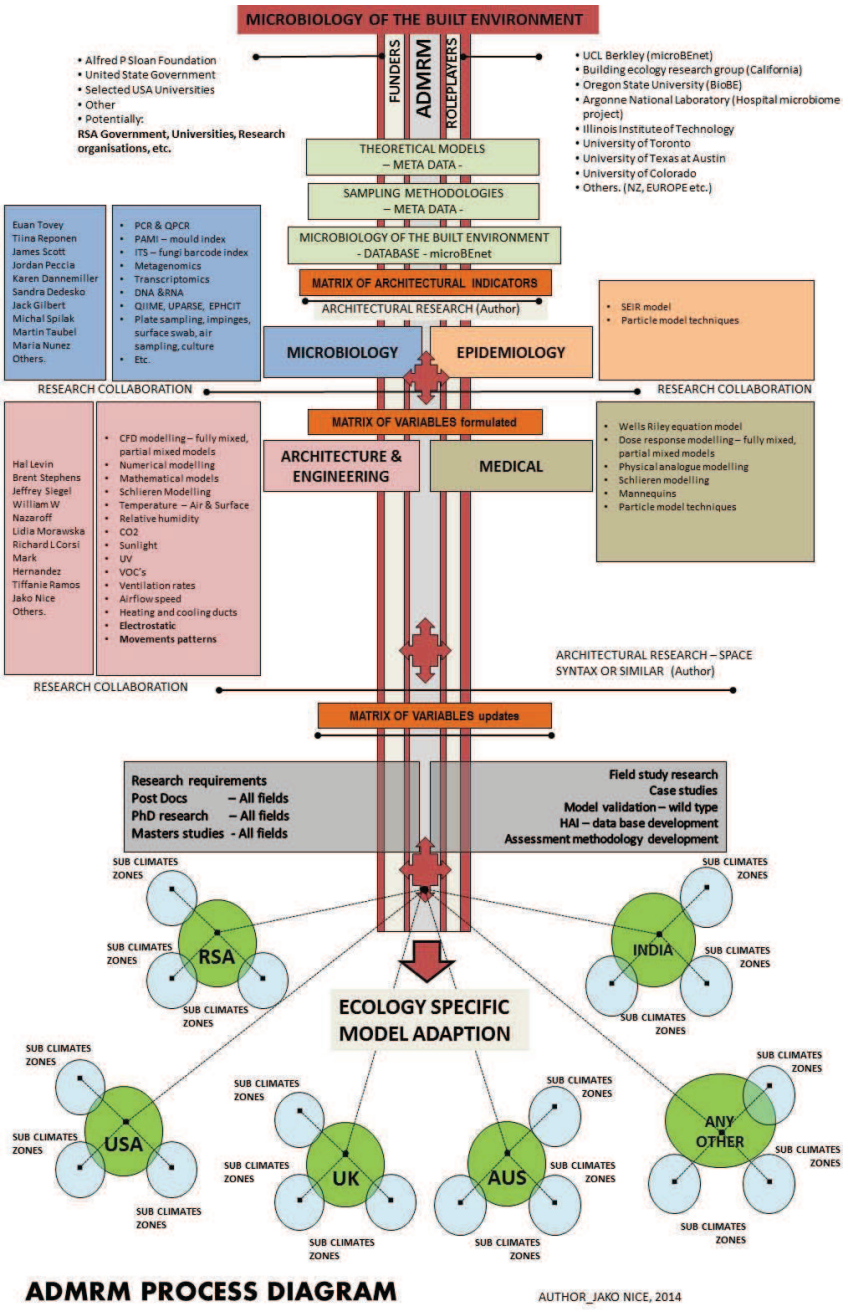


survival based on the stress characteristics of the environment and surface; in addition defining the environment and possible surface type permits development of a chart or matrix of colony formation related to illness, environment and material.
*Where does this leave us: It is evident that architecture and design needs to be informed as to the conditions we are creating and effects of those conditions on our health, a quantification of bacteria and their habitat. This collaboration between Architecture and microbiology is the start of a evidence base for a scientific methodology towards Architectural design and in depth multi-disciplinary research, in developing a consciousness for health in architecture and establishing a new architectural theory within the ecology of building design: '**ecology of architecture: An empiric microbial design construct'**.*
The microbiome concept is still in its infancy: (Rintala. et al. 2008, Michel et al. 2012, Kembel et al. 2013). To continue in their search: How do we establish a relationship and interaction between the environment and the built form: Building ecology, unless one understand the factors and role players that make-up this environment.

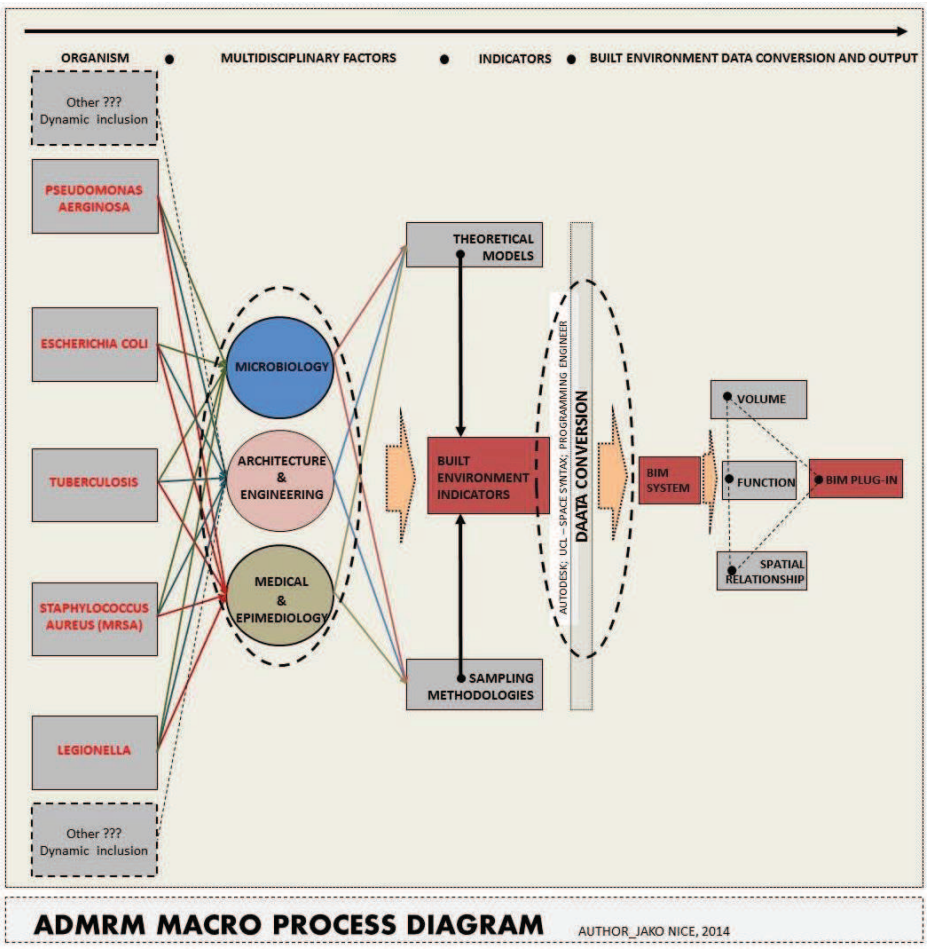
The noted statistics and environmental characteristics - pertaining to South African and international disease epidemics, indoor environments, health care associated infection and the relationship with the microbial environment presents the opportunity to investigate and develop quantitatively the current conditions of the "harmful" or "sick building" and their microbial environments in defining the influential environmental factors, quantifying risk, spatial design relationship and material selection brings us closer to healthy buildings and indoor environments.

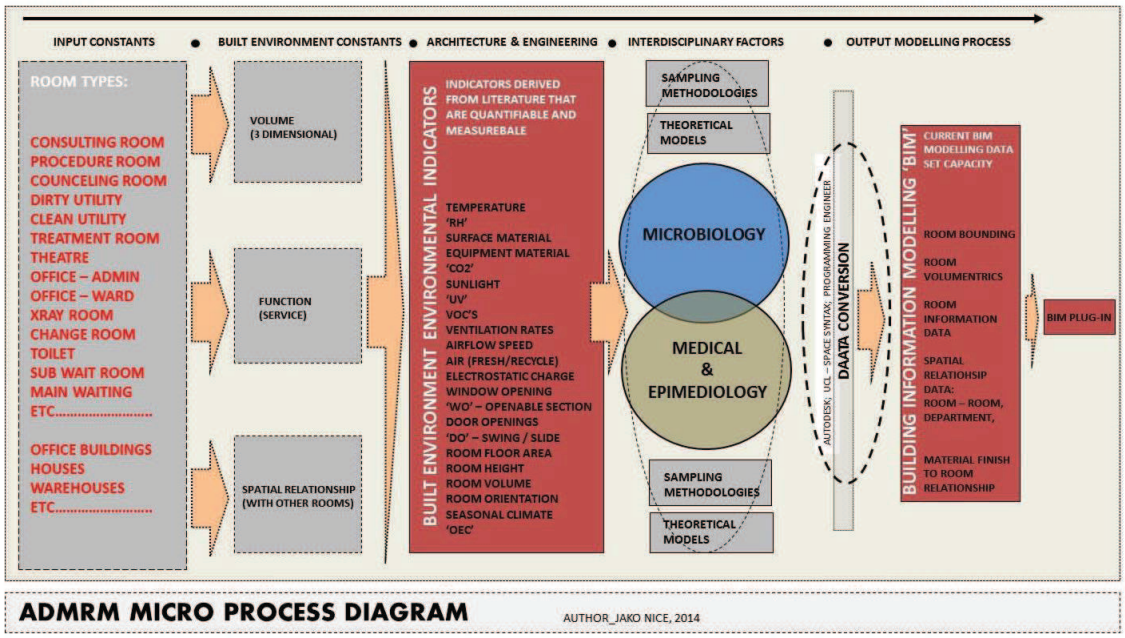
Chapter 2

2.1. Experimental protocol and project overview



Research Project outline & Central research concept





Focused research investigation
Mathematical architecture space syntax theory

Chapter 3

3.1.1. Microbial Experiment Proposal

3.1.2. Problem Statement

What benefit is there in studying the biome of an indoor environment? or…….**D**o we know the health impact of our planning and construction decisions on building users?
Both these questions are inherently the same question. We need to know the ecology of our indoor environment that we may know the impact of our decisions. Studying the indoor biome, studying the human body and studying the methods of bacteria transmission provides tools for designers to relate human health to design planning and space creation.
We do not know what constitutes the indoor biome of any given indoor environment in South Africa, even less a Hospital and more specific an accident and emergency unit (a zone high occupancy and through put of acutely ill people). Due to this fact one cannot relate the suggested design and implemented ventilation strategy or the architectural planning program to the prevalence of certain bacteria organisms in that environment based on its occupancy load. The relationship with bacteria prevalence and architectural planning in user programs have not been studied, yet people are the single largest contributor to bacteria in indoor environments, making the indoor environment a conduit for pathogens.
The implementation of 'green' design principles and the subsequent building regulations do pose health impacts on the wellbeing of patients and users form a transmission perspective; we can measure the energy consumption and the water and waste use, but we cannot relate that to the building biome and health and hence user risk. A study such as this will highlights the need for microbial environments surveillance as part and parcel of the full building system in considering sustainable design.
The impact of airborne disease specifically TB and the co-relationship to HIV can be related to the conditions of indoor environments. The ventilation requirements and the methodology of space use play a fundamental role in the transmission of disease, not only airborne but also touch surfaces.
Compromised patients suffering from HIV (5milj +, of which 70%+ have TB in the WC) are presented with environments that carry airborne TB nuclei and other forms of surface associated bacteria pathogens. The cost to clean and dilute air in these environments have a substantial financial impact on already constrained budgets, in addition developing world countries face the challenges of power outage, poor maintenance, cost and escalation to mention but a few; a sustainable solution needs to be designed into buildings to reduce cost, and promote sustainable infrastructure while providing equitable safe low risk environments for all patients.

3.1.3. Experiment Hypothesis

Microbial experiment hypothesis
The study of the composition of the built environment indoor microbiome and the presence of pathogenic bacteria will provide evidence for co-relationships between the indoor environment conditions, occupancy and the architectural planning program. Postulating potential user health risks emanating from Architectural design planning.

Related hypotheses…

Observational experiment hypothesis: *Observational space analysis provides potential means to study human interaction and functional space use, programmed flow patterns and occupancy duration. Postulating that observational analysis can be utilised (considering disease transmission)*

with investigations of the static indoor environment conditions and the indoor microbial environment to proof the causal health impact of architectural design program and planning,

Environmental experiment hypothesis: *Unremitting monitoring of indoor environmental conditions of the built environment provides potential data that can be correlated to occupancy patterns, functional space use patterns and sustainable conditions for the existence and persistence of microorganism. This study postulates that studying by continuous monitoring of CO2, Temperature and humidity one can provide data that can be attributed to occupancy increase or decrease (architectural planning efficacy and transmission risk), the presence and the persistence of pathogenic organisms (potential environments prone to transmission of disease by incubation)*

3.1.4. **Experiment**

3.1.5. **Environment:**

1. A&E – Khyalitsha Hospital – Hospital A
2. A&E – Mitchells plain Hospital – Hospital B

3.1.6. **Pre sampling test**

1. Prior to sampling a sampling test run will be done, to determine the efficacy of sampling once, twice or three times daily. This will be done twice in a week: at peak and at low occupancy (which will be determined by a questionnaire based on the staff perception) to determine the impact of different sampling days and sampling quantity. Lastly this will be done at one of the two hospitals only, as it should provide sufficient data for final experiment resolution.
2. Day 1 – sample 3x in a single day for a single facility (This will be done for plate and air)
3. Day 2 – sample 2x in a single day This will be done for plate and air)
4. Day 3 – sample only one This will be done for plate and air)
5. Based on the outcome of the proposed pre experiment – Do we find large variation in the different sampling regimes or can a single or two samples be accepted as statistically significant representation of the biome for a day, this will determine the sampling frequency.
6. Based on the variation in services offered each day of the week, and thus a direct impact on the patient profile over the various days, the frequency in number of days within a seven day week will require sampling consideration.

3.1.7. **Number of rooms**

1. The study focuses on the emergency unit of 2 hospitals in Cape Town. Preference is given to high travel zones with most through put of patients, HCW and staff.
2. 5 zones of similar clinical service and or function have been identified in each Hospital.
3. See attached the floor plan of the selected zones of study.

3.1.8. **Sampling types**

1. **Settling plate** (Standard microbiology methodology and equipment will be used, with existing techniques, we refer to the following papers and other as guidance: see also reference list
   (duration of plating (15 min – 45 min require guidance on duration and the planned or expected findings related to that), type of storage, period before analysis, specific environmental

conditions at the time and during the time of collection, room volumetric, design analysis of space, quanta of people moving through the space) type of agar to be determined (use MXIS BE standard set if possible)

2. **Air sampling** (Standard microbiology methodology and equipment will be used, with existing techniques, we refer to the following papers and other as guidance:(Chunyang et al. 2015) see also reference list
    a. Type A: (duration to be determined by professional and literature estimate 30min per sample), type of storage, period before analysis, specific environmental conditions at the time and during the time of collection, room volumetric, design analysis of space, quanta of people moving through the space) type of agar to be determined (use MXIS BE standard set if possible). The selected sampling type: flat membrane filter small enough in size for bacteria collection 5 micro millimetres in size.
    b. Type B: fluorescent particle counter, utilising air sampling methodology with real time particle counting analyses for total particle count. The fluorescent particle counter detects biologic particle concentrations using a fluorescent particle counter. Position and placement: at a height of 1.1 m and was 1.5 m away from solid stationary objects. Samples to be collected at a flow rate of 28.3 L/min for 5 minutes. The recommended experimental settings: the flow rate was 1.0 L/min, the ultraviolet current was 1.46 A, and the photo multiplier tube voltage was 550 V. The counter sample is continuously and records the number of biologic particles

3.1.9. **Experiment Purpose**

1. To determine the total community present in the given environment using both the plate sample collection as well as the various air sample collection. The analysis will be done using pyrosequencing and real time fluorescent particle counting. (total number of organism and identification of the organism - thus community identification)
2. To determine whether the specific high burden HAI bacteria are present in these environment. As per the specified the table below, this includes 2 commonly found on surfaces, and 2 commonly found in the air …These are the most common US nosocomial infection, included Pneumocystis and TB for respiratory purposes, to the knowledge of the author such a list has not yet been developed for South Africa. Utilising PCR to identify the specific bacteria and the presence of all related Geno types in the sample.

Staphylococcus aureus
Pseudomonas aeruginosa
Pneumocystis carinii pneumonia (PCP)
Mycobacteria Tuberculosis

3.1.10. **Sampling Duration**

1. The sampling will be conducted over 2 seasons, as Cape Town represents based on weather data in effect two seasons: Winter and Summer

2. 4 days, for the summer season 2x per day for each Hospital at the same time (settling plates, air sampling), the duration of each sample period is still to be developed based on accredited sampling methods.
3. 4 days, for the winter season 2x per day for each Hospital at the same time (settling plates, air sampling), the duration of each sample period is still to be developed based on accredited sampling methods.

3.1.11. **Number of samples**

1. **Settling plates** – total 160

- KH Hospital A (5 zones) , platting twice a day: at 08:00 and at 16:00; for 4 days; over 2 seasons
    a. Total: Winter – 40, Summer 40
- MP Hospital B (5 zones) , platting twice a day: at 08:00 and at 16:00; for 4 days; over 2 seasons
    a. Total: Winter – 40, Summer 40

2. **Air samples** – total 160
   This will match the settling plate routine central in each zone

- KH Hospital A (5 zones) , sampling twice a day: at 08:00 and at 16:00; for 4 days; over 2 seasons
    a. Total: Winter – 40, Summer 40
- A&E : MP Hospital B (5 zones) , sampling twice a day: at 08:00 and at 16:00; for 4 days; over 2 seasons
    b. Total: Winter – 40, Summer 40

3.1.12. **Analysis**

1. PCR and Pyrosequencing
2. Specific taxa with total gene pool for each sample using PCR analysis for each of the four elected bacteria
3. Pyrosequencing of each sample to determine the full community and quanta of each present in the sample

Staphylococcus aureus
Pseudomonas aeruginosa
Pneumocystis carinii pneumonia (PCP)
Mycobacteria Tuberculosis

4. Total testing by PCR: 320 x 4 = 1280 samples
5. Total testing by Pyrosequencing: 320 x 1 = 320samples

3.1.13. **Assistance**

1. 1x B4 Technician – (this is for both facilities) for setting out plates, collecting plates, included returning samples to the lab.

2. Total time required: 4hrs per day for 14 days: 56hrs total.
3. This will be carried out by a approved and certified company (collection and analysis)

3.1.14. **Sampling options**

a. Option A – Full time 7 days, Air sampling and plate sampling

This is the ideal full study period - (Includes all the sampling variations options and analysis proposed above) however this will be to expense and due to cost this option will not be viable.

b. **Option B – 4 day sampling, Air sampling and plate sampling**

Why? (Due to the variation in efficacy of swab sampling, and considering cost of analysis the potential benefit of swab data could be discarded. in addition considering the peak high and peak low periods for the A&E department could enable considering less days to still provide a statistically significant sample. This presents cost and time savings (considering maximum post sampling pre analysis storage period) .

3.1.15. **Experiment Delineation**

- The proposed study site is limited to the Accident Emergency unit only, and hence findings will be delineated to this environment, it could or could not represent the larger hospital.
- The selected rooms represent the accepted high and medium traffic movement zones in the selected department. Low /limited use zones are not considered based on the possible risk they could represent in relation to the larger department.
- The organisms selected for culture analysis are based on literature studies and most common HAI including high burden airborne disease bacteria as per USA statistics and diseases burden as per WHO report for South Africa - TB. Due to the cost of analysis other organism are not considered in this study, however the full taxa by PCR analysis will indicate potential gene line representation in the environments and thus most likely illuminating related HAI organism.
- Only settling plates and air sampling will be used for bacteria sampling.
- Approved and accepted certified collection, and analysis techniques will be utilised in so doing meeting ISO standards and standard microbiological methodology per bacteria type.
- Sampling duration is based on accepted standards and the pre study results guidance to statistical significance as well as guidance from other studies. See reference list below.
- For air sampling it will be assumed that the room air represents a well-mixed environment, and where mechanical ventilation has been utilised maintenance logs will be will be used to confirm the airflow speed, fresh air quantity, air changes per hour and the pressure differential in certain rooms.
- This experiment provides sampling for a maximum of 4 days only per season, this is due to cost of analysis, and the distribution of days will be determined by peak and low peak times based on pre testing and questionnaire results.
- This experiment considers only 2 seasons as representational of the full variation of climatic conditions over a year in this climatic region.

3.1.16. **Research project objective**

1. It is an accepted fact that indoor environments have the potential to harbour bacteria that are dangerous to human health (pending various factors for airborne and surface); it is an accepted fact that humans are the main source of pathogens in indoor environments (airborne and touch).
    a. To define the distribution of bacteria related to space use and design program.
    b. To understand the relationship of indoor environmental conditions and the persistence of harmful bacteria in indoor space.
2. To relate microbial risk to architectural design for future and existing design guidance. This investigation provides the first data on the South African microbial biome, and specifically in a high burden and transient patient healthcare environment.
3. To analytically compare spatial design layouts with the microbial load distribution and community diversity in both case study hospital sites.
4. To identify risk patterns in design planning (identify and establish universal environmental markers) through investigating microbial community and diversity distribution.

3.1.17. **Value**

1. That architectural design impacts (by secondary nature) user health. Studying the indoor environment enables the designer to consider (as he would consider green systems for energy conservations), building systems and design layout for human health.
   This study contribution intends but not limited to:
    a. Providing evidence that the indoor biome of an environment directly relates to is user, and is a direct consequence of its functional use; more so in hospital environments where function largely determines form and flow.
    b. Providing evidence that spatial configuration do have an impact on disease spread, due to the social engineering aspect of people distribution, the subsequent design can be potentially reviewed and adapted to reduce risk and or restrict disease spread.
    c. Associate and relate human health to environmental risk considering design, providing a platform for intelligent design review tools.
    d. A design tool that informs the designer that his planning layouts presents potential high risk zone, giving guidance as to how do to make changes and guide staff on the most appropriate clinic program within the given building envelope.

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Chapter 4

4.1. Environmental Experiment Proposal

4.1.1. Problem Statement

As designers and built environment specialist we do not fully understand the impact of material choice, architectural planning, building orientation, design typology and even space planning on indoor environmental conditions of the built environments. Studying in real time on a continuous basis 'building life' characterised by elemental parameters such as CO2 levels, temperature fluctuations and levels of relative humidity provides critical data on the way buildings live and breathe in their environment and respond to their users, the ecosystemic conditions they produce and hence provide to microorganisms.

HAI, nosocomial infection and sick building syndrome stems from the very indoor environments man creates and programs for occupancy. This study postulates that it is not only human biology that drives disease transmission, but that the potential for disease transmission can be attributed to both indoor building conditions and the planning program. Studying this relationship between program and indoor conditions provide guidance and evidence for a user health based informed design. The elemental parameters such as CO2, temperature and relative humidity provides clues to the relationship with microorganism prevalence as stated below and occupancy flow and user patterns as stated below. The collective study of these variables by real-time environmental monitoring will provide guidance to building design and managing building related health risk.

With partial reference to the Microbial Experimental Proposal document version 1:

*"**W**hat benefit is there in studying the biome of an indoor environment? or…… **D**o we know the health impact of our planning and construction decisions on building users?*

Both these questions are inherently the same question. We need to know the ecology of our indoor environment that we may know the impact of our design decisions. Studying the indoor biome,

studying the human body and studying the methods of bacteria transmission provides tools for designers to relate human health to design planning and space creation.
We do not know what constitutes the indoor biome of any given indoor environment in South Africa, even less a Hospital and more specific an accident and emergency unit (a zone with high occupancy and through put of acutely ill people). Due to this fact one cannot relate the suggested design and implemented ventilation strategy or the architectural planning program to the prevalence of certain bacteria organisms in that environment based on its occupancy load. The relationship with bacteria prevalence and architectural planning in user programs have not been studied, yet people are the single largest contributor to bacteria in indoor environments, making the indoor environment a conduit for pathogens.
The impact of airborne disease specifically TB and the co-relationship to HIV can be related to the conditions of indoor environments. The ventilation requirements and the methodology of space use play a fundamental role in the transmission of disease, not only airborne but also touch surfaces. "

With partial reference to the Observational Experimental Proposal document version 1:
"The role of spatial design and functional room location relates to design and user program, which in turn directly impacts user interactions. These interactions could potentially be responsible for cross infectious conditions. When studying the science of bio-aerosol flow, pathways and aerosol transmission from person to person and space to space; the space use and layout contribute as a mitigating factor. " "A 'real time' space use (function and flow) by observation and analysis can be utilised to understand and predict human interaction and space use by objective evidential means. A combined study of spatial observation with environmental data logging and microbial sampling could potentially provide tangible interrelationship correlations between risk, environment and space use."

4.1.2. Experiment Hypothesis

Environmental experiment hypothesis
Unremitting monitoring of indoor environmental conditions of the built environment provides potential data that can be correlated to occupancy patterns, functional space use patterns and sustainable conditions for the existence and persistence of microorganism. This study postulates that studying by continuous monitoring of CO2, Temperature and humidity one can provide data that can be attributed to occupancy increase or decrease (architectural planning efficacy and transmission risk), the presence and the persistence of pathogenic organisms (potential environments prone to transmission of disease by incubation)

Related hypotheses…

Observational experiment hypothesis: *Observational space analysis provides potential means to study human interaction and functional space use, programmed flow patterns and occupancy duration. Postulating that observational analysis can be utilised (considering disease transmission) with investigations of the static indoor environment conditions and the indoor microbial environment to proof the causal health impact of architectural design program and planning,*

Microbial experiment hypothesis: *The study of the composition of the built environment indoor microbiome and the presence of pathogenic bacteria will provide evidence for co-relationships between the indoor environment conditions, occupancy and the architectural planning program. Postulating user health risks emanating from Architectural design planning.*

4.1.3. **Experiment**

4.1.4. **Environment:**

3. A&E – Khyalitsha Hospital – Hospital A
4. A&E – Mitchells plain Hospital – Hospital B

1.1. Pre sampling test

7. Prior to sampling/logging a sampling test run will be done for a single day (24 hrs), to check the feedback of the loggers, the weather station and a test run the software with the data collected.
.

4.1.5. **Number of rooms/zones**

4. The study focuses on the emergency unit of 2 hospitals in Cape Town. Preference is given to high travel zones with most through put of patients, HCW and staff. This study will asko include a ward at each hospital.
5. 5 zones of similar clinical service and or function have been identified in each Hospital in each department.

4.1.6. **Sampling types**

3. **Data Logger** – a single manufactured unit by CO2Meter, Inc. Ormond Beach Florida United States, Unit type - CM-0018AA.
   The unit includes built in sensors collecting CO2, Temperature and relative humidity data as well as date and time stamp. The loggers are placed either on a surface approximately counter height: 900mm or will be suspended in the air at 2100mm. The data is recorded via SD Card that will be disseminated on completion of the investigation using GasLab® software – as provided by the manufacturer of the data loggers. The expected battery life of the unit is +- 4-5 days. This will be checked by the assistant to prevent data loss due to uncalculated power down time.
   a. **Temperature** ± 2 °C over full temperature range; Sampling rate: > 1 Hz logging at 1 minute intervals
   b. **Relative Humidity** ± 5% RH over full temperature range; Sampling rate: > 1 Hz logging at 1 minute intervals
   c. **CO2 -** Sampling Method: diffusion; non-dispersive infrared (NDIR); Measurement Range: 0 – 2,000 ppm (0-0.2%); Accuracy: ± 50ppm ± 2.5% of measured value; Sampling rate: > 1 Hz logging at 1 minute intervals
4. **Weather Station -** Ambient Weather WS-1001-WIFI OBSERVER Solar Powered Wireless WiFi Remote Monitoring Weather Station; http://www.ambientweather.com/amws1000wifi.html
   1. **Outdoor temperature** (weather station)
   2. **Outdoor wind direction** (weather station)
   3. **Outdoor wind speed** (weather station)
   4. **Outdoor CO2** (weather station)
   5. **Outdoor Relative Humidity** (weather station)

   Further information such as communication, feature, accuracy and data collection are indicated in the supplier's manual.

1.2. Experiment purpose

To determine the relationship between CO2 levels, humidity and temperature; on occupancy, design and planning as related to the prevalence of microorganisms in an environment. Findings correlated with the outdoor conditions due to the direct impact on naturally ventilated environments.

1.3. Sampling Duration

4. The Relative humidity, temperature and ambient CO2sampling will be conducted over 2 seasons, as Cape Town represents based on weather data in effect two seasons: Winter and Summer
5. 4 days, for the summer season 24hrs per day for each Hospital at the same time.
6. 4 days, for the winter season 24hrs per day for each Hospital at the same time.

1.4. Number of samples

3. **Data loggers**

- KH Hospital A (5 zones) , 1x loggers per zone, 2 departments for 24 hrs, for 4 days in winter and summer
    a. Total: Winter – 96 hrs (Temperature, Relative humidity and CO2), Summer 96 hrs (Temperature, Relative humidity and CO2)
- MP Hospital B (5 zones) , 1x loggers per zone, 2 departments for 24 hrs, for 4 days in winter and summer
    a. Total: Winter – 96 hrs (Temperature, Relative humidity and CO2), Summer 96 hrs (Temperature, Relative humidity and CO2)

4.1.7. Analysis

6. Using GasLab® software – as provided by manufacturer of the data loggers.
7. This will provide information to the average CO2, Temperature and Humidity in each of the zones measured by the loggers.
8. Correlating this data with the observational data will indicate reason for reduction or increase in any of the variables as measured by the data logger. This can be further correlated with the data collected by microbial samplers placed in the same zones and regions as the data loggers and related microbial composition to the measured environmental factors and the spatial occupancy and usage.
9. Statistical analyses assisted by CSIR statistical analyst to determine the significant relationships and correlation of the various data collected. Specific analysis to be confirmed at a later stage.

4.1.8. Assistance

4. 1x Technical assistant – (a single facilitator will be required for both facilities) for setting up the data loggers, testing and checking battery life and finally removing upon completion of study.
5. Total time required: 4days per day season: 8 days total.

4.1.9. **Experiment Delineation**

- The study site is proposed for the Accident Emergency unit only, and hence findings will be delineated to this environment, it could or could not represent the larger hospital.
- The selected rooms represents the accepted high traffic zones in the selected department and thus do not consider the utility and low occupancy spaces.
- This experiment provides sampling for a maximum of 4 days only per season, this is due to cost of analysis, and the distribution of days will be determined by peak and low peak times.
- This experiment considers only 2 seasons as representational of the full variation of climatic conditions over a year.
- Meters used for this experiment provided CO2, RH, Temp. provided by CO2 meters.com See below the manufactured sensor limitations:
    - Measuring Principle: CO2, Non-dispersive infrared (NDIR) sensor
    - Measuring Range: 1% CO2 models 0-10,000 ppm; 30% CO2 models 0-300,000 ppm (0-30% vol.)
    - Repeatability: 1% CO2 models ±20 ppm, ±1% measured value; 30% CO2 models ±0.1%, ±2% of measured value
    - Accuracy: 1% CO2 models ±30ppm, ±3% measured value; 30% CO2 models ±0.2%, ±3% of measured value
    - CO2 Sensor Ratings: Life Expectancy >15 years; Warm-up Time <1 min (instant measurements)
    - Temperature Sensor: Range -40 to 120°C; Repeatability ±0.1°C; Accuracy ±0.5°C
    - Relative Humidity Sensor: Range 0-100%; Repeatability ±0.1%; Accuracy ±3%
    - Dimensions: L x W x D; (mm) inches; (146.1)5.75 x (91.4)3.60 x (32.7)1.30
    - Data Logging: Data Points 15,000 (CM-0016,-0017); 5,400 (CM-0018,-0018AA,-0019,
    - -0209,-0210); Programmable Interval Data Date, time, CO2, %RH, temp.
    - Power: Input Voltage 5VDC (use only supplied adapter); Power Consumption 500 mA (while charging); Charging Time 5-8 hrs. (approximately); Battery Type/Capacity 4xAA (CM-0016,-0017,-0018AA); Li-Ion Battery Lifetime 2-3 years depending on cycles

4.1.10. **Research project objective**

1. It is an accepted fact that indoor environments have the potential to harbour bacteria that are dangerous to human health (pending various factors for airborne and surface); it is an accepted fact that humans are the main source of pathogens in indoor environments (airborne and touch).
    a. To define the distribution of bacteria related to space use and design program.
    b. To understand the relationship of indoor environmental conditions and the persistence of harmful bacteria in indoor space.
2. To relate microbial risk to architectural design for future and existing design guidance. This investigation provides the first data on the South African microbial biome, and specifically in a high burden and transient patient healthcare environment.
3. To analytically compare spatial design layouts with the microbial load distribution and community diversity in both case study hospital sites.
4. To identify risk patterns in design planning (identify and establish universal environmental markers) through investigating microbial community and diversity distribution.

4.1.11. **Value**

As part of three experiments, the collated data of all experiment together provide potential value as described in the microbial experiment protocol Value chapter.

Furthermore this study provides data pertaining to building performance and design use.

4.1.12. **References**

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Chapter 5

5.1. Observational Study Experiment Proposal

5.1.1. **Problem Statement**

With partial reference to the Microbial Experimental Proposal document version 1:

*"**W**hat benefit is there in studying the biome of an indoor environment? or……. **D**o we know the health impact of our planning and construction decisions on building users?*

Both these questions are inherently the same question. We need to know the ecology of our indoor environment that we may know the impact of our design decisions. Studying the indoor biome, studying the human body and studying the methods of bacteria transmission provides tools for designers to relate human health to design planning and space creation.

We do not know what constitutes the indoor biome of any given indoor environment in South Africa, even less a Hospital and more specific an accident and emergency unit (a zone with high occupancy and through put of acutely ill people). Due to this fact one cannot relate the suggested design and

implemented ventilation strategy or the architectural planning program to the prevalence of certain bacteria organisms in that environment based on its occupancy load. The relationship with bacteria prevalence and architectural planning in user programs have not been studied, yet people are the single largest contributor to bacteria in indoor environments, making the indoor environment a conduit for pathogens.
The impact of airborne disease specifically TB and the co-relationship to HIV can be related to the conditions of indoor environments. The ventilation requirements and the methodology of space use play a fundamental role in the transmission of disease, not only airborne but also touch surfaces. "

The role of spatial design and functional room location relates to design and user program, which in turn directly impacts user interactions. These interactions could potentially be responsible for cross infectious conditions. When studying the science of bio-aerosol flow, pathways and aerosol transmission from person to person and space to space; the space use and layout contribute as a mitigating factor. Studying space use and function patterns in healthcare settings provides potential opportunities to mitigate airborne and other disease transmission pathways that are related to people and occupancy.
A 'real time' space use (function and flow) by observation and analysis can be utilised to understand and predict human interaction and space use by objective evidential means. A combined study of spatial observation with environmental data logging and microbial sampling could potentially provide tangible interrelationship correlations between risk, environment and space use.

5.1.2. **Experimental Hypothesis**

Observational experiment hypothesis:
Observational space analysis provides potential means to study human interaction and functional space use, programmed flow patterns and occupancy duration. Postulating that observational analysis can be utilised (considering disease transmission) with investigations of the static indoor environment conditions and the indoor microbial environment to proof the causal health impact of architectural design program and planning,

Related hypotheses…

Microbial experiment hypothesis: (Microbial experiment proposal version 1)
The study of the composition of the built environment indoor microbiome and the presence of pathogenic bacteria will provide evidence for co-relationships between the indoor environment conditions, occupancy and the architectural planning program. Postulating user health risks emanating from Architectural design planning.

Environmental experiment hypothesis: *Unremitting monitoring of indoor environmental conditions of the built environment provides potential data that can be correlated to occupancy patterns, functional space use patterns and sustainable conditions for the existence and persistence of microorganism. This study postulates that studying by continuous monitoring of CO2, Temperature and humidity one can provide data that can be attributed to occupancy increase or decrease (architectural planning efficacy and transmission risk), the presence and the persistence of pathogenic organisms (potential environments prone to transmission of disease by incubation)*

5.1.3. **Experiment**

1.5. Environment:

1. A&E and a hospital ward – Khyalitsha Hospital – Hospital A
2. A&E and a hospital ward - Mitchells plain Hospital – Hospital B

1.6. Pre observation test

Prior to the study observation a questionnaire will be circulated to the staff of the A&E and the selected hospital ward of each hospital to ascertain the peak patient load and venues, as well as personal perception with regards to personal safety and healthcare acquired infection. The purpose for this data is to determine the most appropriate four days of analysis for appropriate correlation with environmental data collection; as well as the personal perceived status quo of HAI. This questionnaire will only be distributed to hospital staff in the specified departments: Ward and Accident and Emergency unit.

Furthermore, a 'dry run' of the route will be conducted prior to the study which will enable the observers to familiarise themselves with the requirements and pathways.

1.7. Observational test Questionnaire

See table of questions (pg5) for pre observational test

No	QUESTION	RESPONSE						
Section A		**Yes**		**Unsure**		**No**		
1	Confirm if you are a hospital staff healthcare worker at this facility?							
2	In which department do you work?							
3	Do you feel safe in your work environment from acquiring airborne disease? (such as TB)							
3.1	If yes response to point 2 - Why?							
3.2	If no response to point 2 - Why?							
3.3	If unsure response to point 2 - Why?							
4	Do you feel that the surfaces in your department are sufficiently cleaned for infection and you are at no risk?							
4.1	If yes response to point 4 - Why?							
4.2	If no to response point 4 - Why?							
4.3	If unsure response to point 4 - Why?							
Section B		**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
5	Which week days do you work?							
6	How long is your work shift?							
7	What time does you shift start and end?							

8	Which week days are busiest in you department							
9	Which week days are the quietest in your department							
10	What times of the day (of the full 24 hrs) do you perceive are the busiest during a busy day							
11	What times of the day (of the full 24 hrs) do you perceive are the busiest during a quiet day							
Section C								
12	Which rooms in your department do you perceive to have high activity spaces							
13	What is the total recorded number of patients in your department on a busy day (as stated in point 10) over 24 hours							
14	What is the total recorded number of patients in your department on a quiet day (as stated in point 11) over 24 hours							

5.1.4. **Area of investigation**

1. The study focuses on the emergency unit and a hospital ward of 2 hospitals in Cape Town. Preference is given to high travel zones with most through put of patients, HCW and staff.
2. A route map of the departments will be developed that will be followed and notations made in accordance with information required.

5.1.5. **Methodology**

The observation methodology used is based on University College London (UCL) Architecture Department, Space Syntax Software manuals. Extracted and compiled from: Space Syntax observational manual developed by Tad Grajewski, 1992 and updated by Laura Vaughan 2001 – UCL Space Syntax. A two task process is to be followed by observers over the period of a day for the study duration (4 days, 2 seasons). As previously indicated, a 12 hour period will be studied at each facility. A single observer will be required to observe for a total of 6 hours per day, thus 2 observers over a 12 hour period for each hospital, totalling 4 observers per day.
Notes: Due to the sensitive nature of the hospital environment care must be taken to ensure appropriate etiquette at all times: such as reporting to the ward nurse before study day commences, keep valid identification and a letter of authorisation and considering patients and their needs.

Observation task 1:

"Mental snap shot" Provide a floor plan at 1:50 scale (A3 Paper size) of the selected department. 'The power of this is that it makes the patterns of space use instantly apparent to a reader or client.

1. Map a route that will cover all rooms that are frequently used to ensure that all spaces (excluding storage areas) are observed (based on pre observation test and questionnaire).
2. Indicate any furniture and divisional change son the plan prior to commencing with the study. If a single space is to large the divide it into smaller zones that are individually assessed.
3. Walk this route once per hour, marking on the drawing in each space the number of people using a coding system.
    a. seated,
    b. standing,
    c. walking, (use an arrow indicting the direction) (do not count people behind you, or any one that enters the zone after your snapshot)
    d. talking,
    e. Dr
    f. Nurse
    g. Other
    h. Patient
    i. as well as the direction of their walking
    j. General occupancy number in the space at that moment in time.
4. Rooms that are locked or deny entry must be marked up with an X.
5. Do this for each room and passage along the route for the next hour, use a new, blank plan to repeat the route (thus for a single department, a total of 48 plans will be required for a 12-hour per day, 4 day observation).

Observation task 2:

"Movement tracer" This technique provides precise routes taken by people moving through space. When compiling this data with the mental snap shot technique one is able to determine use in the space and flow through the space.

1. Similar to task 1, spend 3-4 min in each of the rooms/spaces (4-5 min in the larger spaces – predetermined, and 3 min in smaller spaces – predetermined), marking movements of people entering or exiting the space on a blank floor plan indicated by flow lines.
2. Trace with a pen on the plan all the movement through the space, and conclude the flow line with an arrow where the person exists the space.
3. Define the space use: (using coloured opens to distinguish each one)
    a. Through
    b. To
    c. From
    d. within
4. Do this for each space on the same route map, twice every hour for the duration of the observation period. Use a blank floor plan for the 1st assessment and again a new blank plan for the final assessment.
5. This will be done twice per hour, once before Task 1 and again after Task 1.

5.1.6. Observation Duration

Observation will be done over a 4 day period (the specific days will be determined by the feedback on the questionnaire), this in turn will match the microbial sampling duration. The duration will be a total of twelve hours, over four days at each hospital. Constituting two six hour shifts by 2 observers per hospital.

5.1.7. Analysis

The collected data will be run through Depth map Space Syntax software _, this will provide graphical and percentage flow, use and occupancy over a longer period of time to determine the long term impact of the design program – Refer to Space Syntax Methodology manual, Depths map software: *Al_Sayed, K., Turner, A., Hillier, B., Iida, S., 2014 (2nd Edition), "Space Syntax Methodology", Bartlett School of Graduate Studies, UCL, London..*

"Observations can be used to generate numerical data on space use and movement in urban areas and this data can be correlated with the spatial variables. The most important is between integration and encounters (observed use and movement). We can use the results of observation studies to research social variables: This is because integration is an independent measure - it is the integration value of a space that can produce the people (or the shops and other functional variable) but the presence of more people cannot make space more integrated." (Grajewski, Vaughan 2001)

Correlating the findings with environmental data and microbial data will determine the causal impact of more infected people in the 'said' environment. This enables prediction of transmission. In addition design variations will be run through the program to present the variation in the impact if architectural program and planning is altered. Utilising Space Syntax depthmap software (Al_Sayed et al. 2014), theoretical and quantitative model will be developed to define the space use and flow of each department. When combined with the static environmental data and the microbial sampling correlation between space use and occupant and organism prevalence can be deduced.

5.1.8. **Assistance**

1. 4x Technician/observers – (this is for both facilities) the technicians/observers will be given floor plans of each department with a marked out route. A drawing legend will indicate on the floor plan the required information. The floor plan will be marked up with annotations of: no of people in the space, seated, standing and direction of movement. This will be done once every hour for each department and the set zones as per plan will require a 3 min stop and observe and notate. This will occur for six consecutive hours per person per hospital per shift for four days.
2. Starting time of first shift: 06:00 am, shift change: 12:00am, last shift end: 18:00 pm.
3. Total time required per observer: 6hrs per day for 4 days Over two seasons: 48hrs total.
4. Total A3 printed 1:50 scale floor plans: 3 per hour (for each department) per observer per hospital: 36 floor plans per day per hospital, thus a total of 576 floor plans over 2 seasons

5.1.9. **Experimental Delineation**

1. This study only considers spatial observation data for the period of four days in two seasons as a representation of a an average seven day week over a calendar year
2. The observation period of twelve hours per day, observing on an hourly basis is assumed to represent the daily average usage pattern of the studied environment
3. This study observation are limited to the two selected hospitals: Khyalitsha Hospital & Mitchells plain Hospital and assumes to represent the average space use of high burdened healthcare facilities in South Africa.
4. This study accepts Space Syntax depth map software methodology (peer reviewed and used extensively) for modelling data as collected and appropriate for space use prediction and analysis.

5.1.10. **Research project Objectives**

The objectives of this observation experiments are to:

1) Provide evidence that user interaction is potentially causal of planning design.
2) Define the real time space use program, as this does differ from the initial devised design program.
3) To analytically compare spatial design layouts in both case study hospital sites. To identify user use and movement patterns to health risk in design planning (identify and establish universal environmental markers)
4) Correlate participants' diaries and CO2 data with spatial activity data, (an investigation proceeding in parallel with this investigation), see attached research proposal.
5) To relate both microbial and environmental data with the space use and occupancy,
6) Simply, by graphical means, present user activity of a given environment for further spatial analysis of design flow and space use that will be generated using depth map software

5.1.11. **Value**

As part of three experiments, this observational investigation forms a critical link in relating and identifying the human space use factor to microbial load and environmental conditions. The potential value that this investigation holds is stated in the microbial experiment protocol Value chapter.

Provides an analytical method to analyse space use and program in healthcare settings improving service delivery and potential HAI risk.

5.1.12. **References**

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RESEARCHER DECLARATION

APPLICATIONS MUST INCLUDE THE FOLLOWING STATEMENTS

Hereby I, ……Jako Albert Nice …… in my capacity as……Doctoral student researcher……., that

1 Research subjects will be informed, information will be handled confidentially, research subjects reserve the right to choose whether to participate and, where applicable, written permission will be obtained for the execution of the project (example of permission attached).

2 No conflict of interests or financial benefit, whether for the researcher, company or organisation, that could materially affect the outcome of the investigation or jeopardise the name of the university is foreseen.

3 Inspection of the experiments in loco may take place at any time by the committee or its proxy.

4 The information I furnish in the application is correct to the best of my knowledge and that I will abide by the stipulations of the committee as contained in the regulations.

5 Signed: _____ Date: _31 March 2015___

CSIR Built Environment
PO Box 395 Pretoria 0001 South Africa
Tel: +27 12 841 3993
Fax: +27 12 349 3539
Email: query@csir.co.za

Attention: To whom it may concern

Addendum to Protocol title - Building airborne risk estimation – Occupant population re-breathed air fraction.
HREC REF Number: 239/2015; Principle Investigator – Dr. Carl Morrow
Cover letter - Form FHS007: Amendment – study staff

Request for amendment and addition to current approved study HREC REF: 239/2015

This submission is in accordance with the requirements to submit for changes in both researchers and addition in protocol on the current research work for HREC REF 239/2015 titled: Building airborne risk estimation – Occupant population re-breathed air fraction

Mr Nice is registered for a PhD in Architecture at the Department of Architecture, Faculty of Engineering, Built Environment & IT at University Pretoria (UP). He is also a CSIR researcher and Fogarty Fellow with the other co-investigators as per the submitted and approved research proposal.
At the time of submission the PhD ethics approval for Mr. Nice was still underway at the UP.
However, to ensure that correct protocol was followed as required by both UP research and ethics and UCT ethics, it was advised that Mr. Nice exclude his portion of the protocol and position as PhD research candidate until research ethics approval was received from UP ethics board.

Ethics approval has since been granted by UP ethics board and the relevant proof is attached to this submission. This document submission includes both the ethics approval letter and the additional research protocol for re-submission as part of the Dr. Morrow's approved study.

The requested additional investigation which will form part of the approved project includes a microbial investigation of the indoor environment, with observational analysis and static environmental data collection. The latter investigations have already to a large extent been included in the approved project. It is the intention of the study to utilise Dr. Morrows study design to structure Mr. Nice's investigations.

I trust you will find the request and protocol summary in order

Regards
Jako Albert Nice
CSIR researcher, PhD candidate