



SIMULATION-BASED
MOCK-UP
EVALUATION

Framework
MARCH 2016

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CONTENTS

FOREWORD	2
INTRODUCTION	3
Need for a framework	3
Purpose and goals of the framework	4
Intended audience	4
Principles of the framework	4
METHODS AND BENEFITS OF GAINING USER INPUT IN DESIGN	5
User input into designs	5
Range of architectural evaluation methods	6
Costs and benefits	7
Supplementary expertise	9
EVALUATION PLANNING	10
Spaces to evaluate	10
Consideration for an evaluation	10
Scope of the evaluation	12
Timing of the evaluation	12
Iterative design and evaluation	14
DESIGNING AND BUILDING A MOCK-UP	14
Simple mock-ups	16
Detailed mock-ups	16
Live (functional) mock-ups	17
SIMULATION ROLES AND RESPONSIBILITIES	21
Simulation preparation	21
Enacting simulation scenarios	25
Data collection and analysis	26
Disseminating findings and recommendations	29
Tracking and evaluating implemented recommendations	30
SUMMARY	30
APPENDICES	31
Appendix 1: Listing of evaluation tasks	32
Appendix 2: Simulation scenario template	33
Appendix 3: Sample pre-briefing script and instructions	34
Appendix 4: Photography suggestions	36
Appendix 5: Videography suggestions	37
Appendix 6: Data analysis spreadsheet template	38
Appendix 7: Recommendations template	40
ACKNOWLEDGEMENTS	41
REFERENCES	43



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FOREWORD

The physical space, equipment, and people within any healthcare environment have a bearing on patient experience. The size and design of a hospital room and the placement of equipment, for example, influence how healthcare teams and individuals interact to perform their work. A poorly designed space can inadvertently introduce hazards both for the patient and healthcare workers and many of these scenarios can be anticipated and avoided by involving users in the design process to help the end product meet their needs. An important tool for gathering users' input is

designing and testing mock-up environments, where users perform their typical roles in the mock-up space as if in a real-life scenario. This approach shows how healthcare professionals use and interact with the space, medical equipment, one another, and the patient so that the design can address any challenges that might otherwise have been overlooked. A better design process can improve patient safety, staff efficiency, user experience, and can yield financial returns as well.

This *Simulation-Based Mock-up Evaluation Framework*, developed by the Health Quality Council of Alberta (HQCA) in collaboration with experts in human factors, healthcare design, and patient simulation as well as provincial and national stakeholders, outlines an approach to collect and analyze data from mock-up healthcare environments. Portions of this framework were developed based on project experience and expertise of human factors teams at Alberta Health Services, W21C, and the University of Calgary. This framework is intended to be a guiding document to support the evaluation of mock-ups from which an improved design process can result.

The HQCA was supported in this work through the generous contributions of time and talent from various stakeholder groups and individuals, with the shared goal of achieving better outcomes for patients. Many people with specialized knowledge in designing safe, high-quality environments participated in the process of creating and reviewing this framework. We gratefully acknowledge their efforts.

Andrew Neuner
Chief Executive Officer, HQCA
March 2016

INTRODUCTION

Patient and staff safety as well as other patient and staff outcomes are strongly linked to the built healthcare environment in critical ways. Infections, patient falls, and other complications of care, including surgical complications and increased length of stay, as well as healthcare worker injuries are all affected by the built environment.¹⁻⁴ Such adverse outcomes can be the result of decisions made during the design process that can inadvertently introduce design flaws in the system, known as latent conditions.⁵ All decisions, even correct ones, have the potential to introduce latent conditions.

These design decisions can contribute to adverse events in healthcare settings.⁶ Basing these decisions, which are made early in the design process, on evidence-based data will improve outcomes. This framework describes a systematic way to do this using human factors/ergonomicsⁱ methods to test and optimize design for safety with representative user groups. It is applicable to a wide variety of stakeholders including those who initiate, plan, or participate in the design process of built environments for healthcare. Applying this framework is expected to yield cost efficiencies as well as improve patient safety, staff efficiency, and the experience of patients and staff who use the space.



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NEED FOR A FRAMEWORK

Various human factors methods can and have been used to conduct and extract information from simulation-based mock-up evaluations.⁸⁻¹⁵ A mock-up is a prototype or model of a design that is used for teaching, demonstration, design evaluation, or other purposes to enable testing of a design.¹⁶ For this framework, the term mock-up refers to those which are built at full scale. Simulation, for the purpose of this framework, refers to the enactment of relevant tasks, performed by individuals or teams, while interacting with the mock-up, potentially with real patients and their families. Patient simulation is more commonly used for clinical training; however, in this case the focus is on how well the built environment supports performance. Little guidance is available for organizations and healthcare design teams that want to extract more evidence-based data from their mock-ups.

Although the use of full-scale mock-ups to gain user input can be valuable and is growing in popularity, the use of simulation within a mock-up is less frequently employed. This may be due to a lack of guidance outlining how simulation data can be collected, analyzed, and used to enhance the design of the built environment. Watkins and colleagues have cautioned that simulation within mock-ups will deliver a lackluster performance if the approach does not include a carefully orchestrated research setting and process.¹⁷

ⁱThe International Ergonomics Association defines, later adopted by the Human Factors and Ergonomics Society, Human Factors/Ergonomics as “the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.”⁷

NEED FOR A FRAMEWORK – continued

Designing and building environments that facilitate safer, more efficient, and cost-effective care is increasingly important. In anticipation of a growing population as well as aging facilities, changing technology and methods of delivering care, many provincial governments are heavily investing in healthcare facilities. The Alberta government budgeted \$2.2 billion to build and expand health infrastructure in its five-year (2015-20) capital plan.^{ii, 18} The British Columbia government budgeted \$2.7 billion on health infrastructure over three years (2015-18).¹⁹ The Ontario government budgeted \$11 billion in hospital capital grants over 10 years (2015-26).²⁰ Given the substantial investments in healthcare infrastructure, optimizing the design of planned facilities is critical. Therefore, there is a need for a simulation-based mock-up evaluation framework; one that can be useful across jurisdictions sharing similar goals.

PURPOSE AND GOALS OF THE FRAMEWORK

This *Simulation-Based Mock-up Evaluation Framework* builds upon extensive experience using and refining the evaluation methodology in a variety of healthcare environments across Alberta. Participation of stakeholders with broad expertise in this area, as well as a review of pertinent literature also guided the development of this framework. The framework outlines an approach to collect and analyze data from full scale mock-ups, through the use of simulation, where individuals enact processes and procedures that will be performed in the space. It provides an opportunity to meaningfully engage planned users of the space, including patients and healthcare professionals, into the design process. Data from the simulation-based mock-up evaluations are intended to guide design decisions in efforts to optimize the built environment for safe and efficient patient-centred care.

The goals of the framework are to:

- Enhance awareness and use of simulation-based mock-up evaluations.
- Assist with planning for an evaluation, as applicable, before the design process starts.
- Provide guidance for individuals/organizations to conduct a mock-up evaluation.

INTENDED AUDIENCE

This framework is intended for all individuals and organizations involved in the design process of healthcare environments. This includes government, healthcare administrators, planners, and architects. It is also applicable to individuals, teams, and organizations that research the built environment, or provide expertise to optimize built environment design including human factors specialists, simulation consultants, quality improvement consultants, and academics. And finally, it is applicable to those who will be using the designed environment including patients, families, healthcare professionals and staff.

PRINCIPLES OF THE FRAMEWORK

1. A simulation-based mock-up evaluation should be considered, and if applicable, planned, as part of the pre-design stage for inclusion in the design stage.
2. The mock-up evaluation should be thoroughly planned to maximize effectiveness. The scope of the evaluation should be outlined during pre-design (during or just after functional programming). It should include evaluation objectives, time and costs required to build and evaluate a mock-up, and identify which phase within the design stage the evaluation should occur. The evaluation should occur before finalizing design decisions that the evaluation is intended to inform.

ⁱⁱ In Alberta, projects \$5 million and greater (major projects) are generally managed by Alberta Infrastructure whereas projects under \$5 million (minor capital projects and infrastructure maintenance programs) are generally managed by Alberta Health Services.

3. **Building of the mock-up should align with evaluation timing and objectives.** The degree to which a mock-up is completed (mock-up fidelity) can vary significantly. The mock-up should be built to an appropriate level of fidelity to enable testing of evaluation objectives during the appropriate design phase.
4. **Roles and responsibilities for those involved in the evaluation should be clearly defined.** This includes identifying who will be responsible for evaluation design, staging the mock-up, data collection, and data analysis as well as who will participate in the scenario enactments. Availability of expertise (e.g., human factors) should be assessed to identify if individuals external to the organization are needed.
5. **The simulation scenarios that are created and enacted should test the evaluation objectives.** Evaluating a mock-up involves selecting frequent, urgent, and challenging tasks to create simulation scenarios that will test predetermined evaluation objectives. The scenarios are enacted by users of the space within the mock-up, which includes needed supplies and equipment (real or mock-ups).
6. **Recommendations should be informed by evidence-based data from scenario enactments.** Evidence-based data, collected through user feedback and video analysis, is used to identify potential issues and successes with the planned design. The recommendations that are developed should address any identified issues.

METHODS AND BENEFITS OF GAINING USER INPUT IN DESIGN

USER INPUT INTO DESIGNS

Designing or renovating a built environment to support and facilitate patient care is a complex process. An important component in human factors evaluations is the incorporation of users' input (a form of participatory ergonomicsⁱⁱⁱ) into the design process to help ensure the space will meet the needs of each group of users. Depending on the room being designed, users may include healthcare professionals such as physicians, nurses, pharmacists, and/or allied health professionals.

Support staff such as protection services, facilities maintenance and engineering, porters, and housekeepers may also be included, as may patients and their families. Different patients will have diverse needs within the same space and across different healthcare environments, be it a hospital, long term care facility, ambulance, or outpatient clinic. Similarly, wheelchair users, people with disabilities, and able-bodied individuals may all interact differently with built environments. Input from all users is critical. This is consistent with provincial, national and international recognition of the important role that patients and their families play in health quality improvement.²³ Meaningful engagement from all user groups can enhance patient experience, remove latent conditions or hazards for patients and staff, reduce conflicts (i.e., bumps) between equipment and people, and improve efficiencies in the final design.



Photo courtesy of Alberta Health Services

ⁱⁱⁱ Participatory ergonomics is defined as “the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals”.²¹ Hignett and colleagues reviewed the benefits of participatory ergonomics across a range of industries, including healthcare.²²

RANGE OF ARCHITECTURAL EVALUATION METHODS

Design teams soliciting feedback from users can share two-dimensional (2D) drawings, three-dimensional (3D) renderings that allow animated walkthroughs, renderings depicting more spatial qualities, virtual reality environments, and physical models (e.g., mock-ups) at various scales to communicate architectural designs.²⁴ The method selected should reflect the degree of precision and detail sought in the feedback provided from the user groups. For example, 2D drawings are commonly used to gather user input through focus groups or meetings, and in some cases tabletop exercises are used to walk users through clinical processes on top of a 2D drawing.²⁵ Feedback obtained through use of 2D drawings may be compromised, however, due to difficulties with conceptualizing how big the actual space will be. Furthermore, 2D drawings are not always easily interpreted or understood by those who do not view them regularly.

There is a growing trend to build full-scale mock-ups that allow users to experience a replica of the planned space, provide feedback, and then move outlets, equipment, walls, and anything else needed to achieve a desired configuration.^{17, 26} Although having users walk through a mock-up and inspect the planned room helps them to better visualize the space, how the space will support both current and planned uses might not be clear. Potential design issues may remain hidden, especially if the space, once filled with equipment and supplies, is then used by users in ways unanticipated by designers.²⁷ Furthermore, it is difficult to move beyond assessing hazards associated with a single technology to assess the complete context and understand how multiple technologies will work together, and the hazards introduced when interacting with multiple technologies simultaneously.²⁸ Simulating various processes and procedures anticipated for the space can help the design team understand the clinical processes that the built environment is intended to support and the implications when multiple users use the space simultaneously.

Simulation within mock-ups allows design teams to test, refine, and discover new design concepts based on anticipated processes and procedures.¹⁷ Evaluation objectives can target the testing and optimization of (1) room size and configuration; (2) space requirements; (3) access requirements; (4) equipment and supply placement; (5) visibility of the patient, equipment, and monitors; (6) work flows and processes; as well as (7) user experience. These objectives are quite different from simulations which focus on clinical skills or process/culture improvement, and consequently, the scenarios and data collected will likely differ. Using simulation within a full scale mock-up allows design teams to experience and test design ideas before construction.^{9-15, 29-31}

Within Alberta, the use of simulation to evaluate mock-ups has been undertaken as part of the design process for a number of new builds, primarily those focusing on acute care spaces in Calgary (see Table 1). These evaluations provided opportunities to develop, use, and refine the evaluation process through lessons learned, and this framework builds upon those learnings.

TABLE 1: Simulation-based mock-up evaluations conducted to design healthcare facilities in Alberta

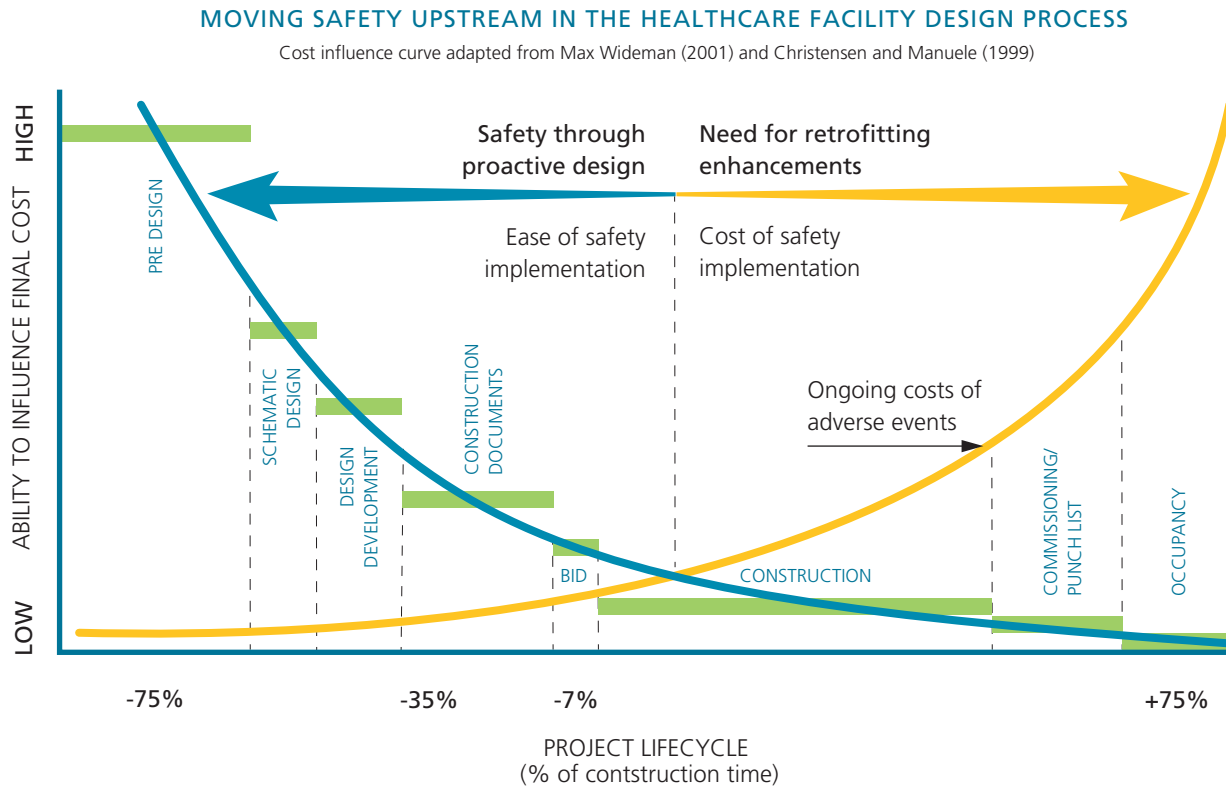
Room type	City	Facility
Hybrid operating rooms	Calgary	Foothills Medical Centre (cardiovascular) ³²
	Calgary	Peter Lougheed Centre (vascular) ³³
	Edmonton	Mazankowski Alberta Heart Institute (cardiac) ³⁴
	Calgary	Foothills Medical Centre (interventional trauma) ^{11,14,35}
Intensive care unit patient rooms	Calgary	South Health Campus ³⁶
	Calgary	Foothills Medical Centre ¹⁰
	Calgary	Peter Lougheed Centre ¹⁰
Emergency department exam rooms	Calgary	South Health Campus ³⁷
Ambulance patient compartments	Provincial	Emergency Medical Services ³⁸
Acute care unit patient rooms	Calgary	South Health Campus ³⁹
Designated assisted living resident rooms	Provincial	Facility design standards and guidelines ²⁹
Outpatient exam rooms	Calgary	South Health Campus ⁴⁰
Medical day unit pods	Grande Prairie	Grande Prairie Regional Hospital ⁴¹
Systemic prep rooms	Grande Prairie	Grande Prairie Regional Hospital ⁴¹

COSTS AND BENEFITS

Simulation-based mock-up evaluations can lower costs, as well as improve patient safety, staff efficiency, and user experience. The ability to make design modifications diminishes as a project moves through the design process, and ultimately affects what is in and out of scope for an evaluation. Early user input into the design process allows for greater influence on both safety and the final cost, as it is less expensive to implement safety enhancements early in the project lifecycle (see Figure 1). Conducting a mock-up evaluation during the correct phase in the design process is essential for maximizing the benefits of the evaluation.

The cost to build a mock-up might include construction, consultant fees, or rental space. The amount is highly variable and dependent on a variety of factors including the level of fidelity (i.e., how elaborate the mock-up is, as described on page 16). Table 2 outlines approximate cost ranges for each fidelity type, which are based on reported amounts from Alberta Infrastructure and Alberta Health Services (AHS) to build mock-ups. The cost of personnel to conduct and participate in the evaluation will depend on whether in-house expertise and in-kind support are available. Given that five to 15 per cent of a construction budget can be used making design-related changes during construction (two to three per cent is commonly considered acceptable), Johansson advocated for the use of mock-ups, which in one example cost 0.5 per cent of the construction budget (and often less), to identify issues before construction.²⁴

FIGURE 1: The cost-influence curve⁴²



In Alberta, simulation-based mock-up evaluations resulted in net savings estimated at \$1.7 million. This was achieved through a series of evaluations that examined four mock-ups, which informed the design template for 900 patient rooms at the South Health Campus in Calgary (see Figure 6).⁴⁵ Savings were gained through avoidance of change order requisitions and were calculated using direct costs only. Additionally, had the changes been made after opening the hospital, this would have resulted in a loss of an estimated 940 patient bed days. Design changes made as a result of the evaluation included reconfiguring the bathroom, headwall, and the addition of data and electrical outlets. These changes are representative of a different type of value where changes made during design could minimize or avoid 40 or 50 years of inconvenience.⁴⁴ Indeed, the magnitude of cost savings will differ between projects.

TABLE 2: Approximate costs to build a mock-up

Mock-up fidelity	Approximate cost range to build
Sample mock-up	\$440 – \$25,000
Detailed mock-up	\$51,000 – \$158,000
Live (functional) mock-up	Uses built and fully functional rooms

Improvements in patient safety and staff efficiency have also been demonstrated. Specifically, the number of bumps between people and/or equipment was reduced by 44 per cent in one area of an interventional trauma operating room mock-up at the Foothills Medical Centre (see Figure 7). This was measured by enacting the same scenario before and after implementing design changes and comparing bump data between the two scenario enactments.¹⁴ Bumps are indicators of physical congestion and potential contamination risk (particularly when sterile and non-sterile items come into contact). Design changes included relocating supply cabinets for better access, as well as moving one wall, ceiling-mounted articulating arms, and the surgical table, to increase available space.



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Involving clinical teams in the simulations, and ultimately the design process, enhances their level of comfort with providing patient care in new facilities.⁴⁵ Team involvement also provides the opportunity to practice and improve task performance, skills, and team work. For example, the time required to position a C-arm in a hybrid operating room was decreased from four minutes, eight seconds to one minute, 20 seconds through the participation of operating-room team members in four scenario enactments.⁴⁶ This represents a two minute and 48 second reduction in the time required to have a potentially life saving diagnostic test performed. Furthermore, participating in the simulations can engage or re-engage these teams in the design process.

Involving members of the public or patient and family advisors as participants in the simulations can help foster and maintain patient-focused design. For example, seniors living in a supportive living facility played the role of residents in a mock-up evaluation of a resident's room (see Figure 5). Design specifications that resulted from involving these members of the public included ensuring unobstructed turning radius of a wheelchair on at least two sides of the bed, room reconfiguration options for alternate bed locations, and views of the outdoors when both sitting and lying in bed. These design solutions are expected to enhance the residents' experiences.²⁹

SUPPLEMENTARY EXPERTISE

It should be remembered that a simulation-based mock-up evaluation is only one of many tools both within human factors and other areas of expertise that can be used to evaluate the built environment. Mock-up evaluations do not negate the need to consider other methods (e.g., tabletop exercises, usability testing, post-occupancy evaluations) as well as other areas of expertise (e.g., infection prevention and control, process improvement, occupational health and safety, ergonomics) to optimize design. Engaging all appropriate stakeholders and experts throughout the design process is necessary. Simulation-based mock-up evaluations provide a venue for potential collaborations.

EVALUATION PLANNING

This section outlines important considerations for planning a simulation-based mock-up evaluation. This includes what types of rooms would benefit most from a mock-up evaluation, when to start considering and planning for an evaluation, determining the evaluation scope, and identifying the optimal point in the design process to conduct the evaluation.

SPACES TO EVALUATE

Nationally, the *Canadian Health Care Facilities Z8000* standard, published by the Canadian Standards Association, recommends building a mock-up for areas with multiple interrelated activities, complex traffic flows, repetitive design in room types, complex projects, and for projects working within or next to an existing facility to minimize disturbances to surrounding services.⁴⁷ This standard provides requirements and guidance for the planning, design, and construction of Canadian healthcare facilities. Although there is significant variation in how these mock-ups can be used, this framework recommends considering a simulation-based mock-up evaluation for:

- Room design templates, such as standardized (or highly repetitive) patient rooms used throughout a facility.
- Rooms with higher potential for adverse outcomes, such as those that provide operative or invasive procedures.
- Highly technical spaces with complex design requirements, such as a patient room in an intensive care unit.
- Innovative room designs, such as those tailored around technological advancements, such as a hybrid operating room.
- Rooms that foster new team relationships, such as bringing together inter-professional groups that have previously not worked together.
- Innovative or new work processes that need to be developed or reviewed, such as a change from centralized to bedside charting.
- Expensive rooms with consideration to both their building and operating costs, such as a hybrid operating room.
- Rooms with a known history of contributing to adverse events or worker injuries.
- Anticipated user resistance to the room design.

CONSIDERATION FOR AN EVALUATION

A capital program or project includes three stages:

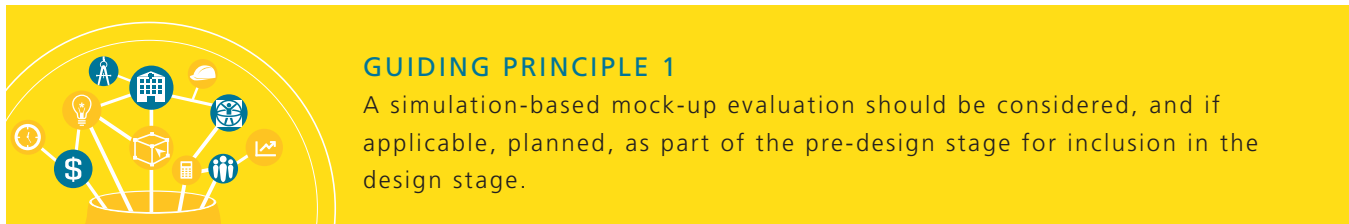
- Pre-design
- Design
- Construction/commissioning

In Alberta, the *Health Facilities Capital Program Manual* describes the responsibilities, accountabilities, and processes for the planning and delivery of a capital program or project delivered by the Alberta government.⁴⁸

Pre-design typically begins with an evaluation of existing spaces, often to address deficiencies or changes in service delivery. This involves conducting a needs assessment that articulates clinical needs, or gaps, between current conditions and desired outcomes and includes a preliminary risk assessment. If the needs assessment is approved by government then a business case is prepared, which is a systematic process to

evaluate different options and develop a facility solution that meets the requirements identified in the needs assessment. Information from the business case, if approved and funded as part of the capital plan, would then be incorporated into the project management plan, functional program, and overall project schedule. The functional program details the scope of services for a new facility that a project must address and functional requirements that must be met. The functional program is used to provide instruction and clarification during the design stage.

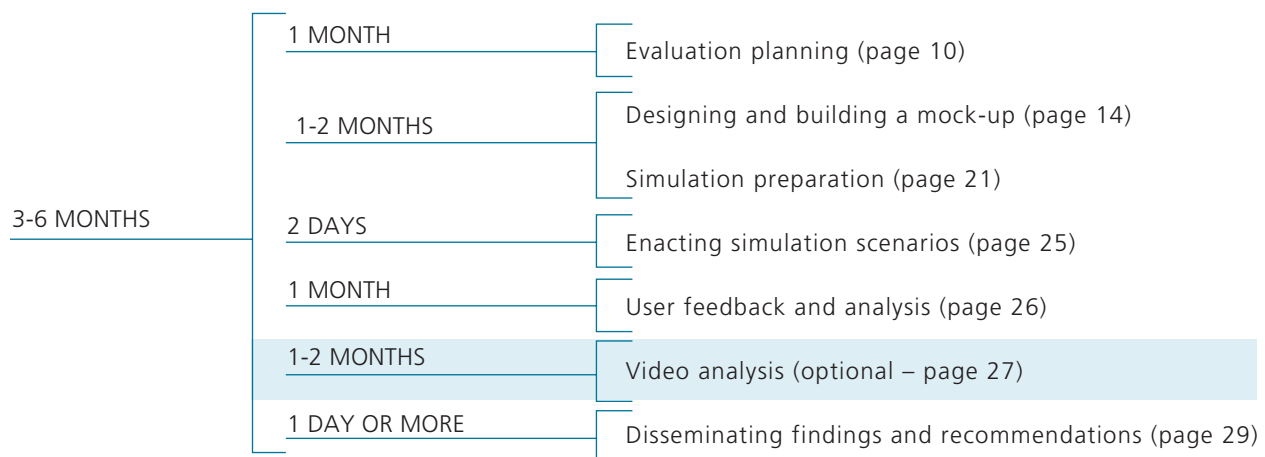
It is during the pre-design stage when a simulation-based mock-up evaluation should be considered for inclusion in the design stage. If applicable, the business case and/or functional program would state that consideration be given to conducting a simulation-based mock-up evaluation or that an evaluation be required during the design stage.



GUIDING PRINCIPLE 1
A simulation-based mock-up evaluation should be considered, and if applicable, planned, as part of the pre-design stage for inclusion in the design stage.

If proceeding with a plan to conduct a simulation-based mock-up evaluation, the scope of the evaluation (see page 12), design phase when the evaluation should occur (see Figure 3), time required to conduct the evaluation (see Figure 2), and costs to build a mock-up (see Table 2) should be outlined during or just after functional programming. Preparing for and conducting an evaluation typically takes between three and six months, but will vary depending on whether video analysis is performed, the number of participants in the simulations, the number of scenario enactments, and the time required to build a mock-up. Many of the steps can occur simultaneously with other planning and design activities. Video analysis extends what is learned through user feedback by providing evidence-based data that is more quantitative and objective, and can be used to support or refute recommended design changes, resolve disagreement on the value of particular design elements, or create a more detailed understanding of room use. This approach is discussed in more detail in the video analysis section on page 27.

FIGURE 2: Approximate time requirements to prepare for and conduct a simulation-based mock-up evaluation



SCOPE OF THE EVALUATION

Evaluation objectives, which outline what will be tested for both design and outcomes, need to be identified. These are often determined by the design team in collaboration with the evaluator or evaluation team. Together the objectives form the intended scope of the evaluation and are critical for many subsequent steps in the evaluation process. Evaluation objectives may include, but are not limited to, the assessment of:

- Unit configuration
- Room size
- Design or design feature comparisons
- Space requirements for equipment or processes
- Access to the patient and/or equipment
- Patient/family spaces and experiences
- Patient transport routes to and from the room
- Room configuration
- Furniture, fixtures, and equipment placement (e.g., headwall configuration, sink locations)
- Furniture, fixtures, and equipment usability
- Visibility of patient, monitors, supplies (e.g., alcohol-based hand rubs), and/or equipment
- Supply placement
- Adverse events, such as those pertaining to infections, patient handling, medication safety, falls, behavioral health, and security⁴⁹
- Work flows and processes
- Team functioning/performance

TIMING OF THE EVALUATION

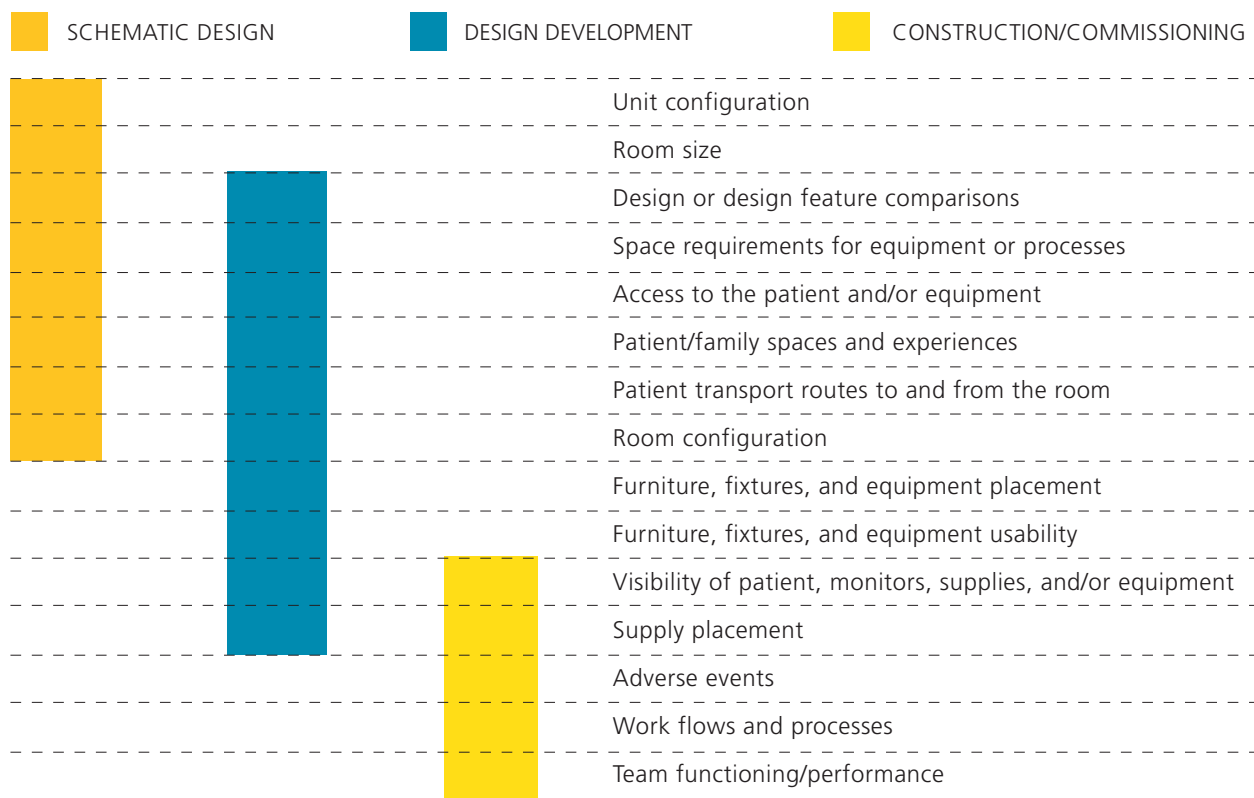
The design process follows a schedule, typically outlined in a project management plan, and produces a design that incorporates functional requirements. The functional requirements are identified in a functional program which describes the scope of services to be addressed by a project and are used during design to provide instruction, scope clarification, project costing and estimated operating costs. The Royal Architectural Institute of Canada outlines five phases of the design process.⁵⁰ These include:

1. **Schematic design phase** – review program requirements and develop documents, which include floor plans, to illustrate scale and character of the project as well as how the parts functionally relate.
2. **Design development phase** – further develop schematic design floor plans into drawings and other documents to outline architectural, structural, mechanical, and electrical systems, materials, and any other elements as appropriate.
3. **Construction documents phase** – further develop drawings and documents to prepare specifications and construction documents that detail the requirements for the construction of the project.
4. **Bidding and negotiation phase** – obtain bids or negotiated proposals, award, and prepare contracts for construction.
5. **Construction phase** – construct the project, which involves monitoring for progress and defects based on the interpretation of construction documents, potentially producing renderings to clarify specifications in construction documents, and preparing change orders and change directives as needed to modify or extend construction.

Commissioning, although not specifically listed as a design phase, is a quality-oriented process of inspection and functional performance testing for all design requirements prior to occupancy. Development of a commissioning plan starts during design (potentially following the schematic design phase). This often dovetails with *operational commissioning* which details the clinical and non-clinical operational and move-in requirements to relocate staff and patients into a facility. This includes activities such as orientation and training of staff, dry runs, and testing of procedures and equipment. Operational commissioning starts during the pre-design stage and ends with occupancy. Planning the move may begin early in the design process while the actual move-in could be phased in over a set time period in order for the project to be fully operational.

Deciding when to conduct an evaluation should be based on predetermined evaluation objectives (i.e., the evaluation scope) and may require that evaluations be performed at more than one phase in the design process. Figure 3 illustrates the design phase(s) most applicable to various evaluation objectives.

FIGURE 3: Design phase(s) most applicable to various evaluation objectives



ITERATIVE DESIGN AND EVALUATION

Iterative design is a concept that involves testing, analyzing, and refining design through a cyclical process. This process could involve conducting a series of simulation-based mock-up evaluations at various design phases, each with differing evaluation objectives. For example, a mock-up to assess space requirements and room size during the schematic design phase would be modified according to the evaluation findings. The modified mock-up would then be re-evaluated to also assess equipment placement and usability during the design development phase with findings again incorporated into the mock-up. A final re-evaluation of the mock-up during construction/commissioning would then assess workflows and team performance. With each modification, additional design details would also be incorporated into the mock-up to make the space appear more completed and realistic for the subsequent evaluation. Iterative design concepts can have a large effect on the design schedule, but depending on the project may be time well spent.

Multiple evaluations may also occur within a design phase if significant design modifications are made following an evaluation (e.g., room re-configuration) that warrant subsequent re-testing. For example, if the location of a patient's bed was changed to a different wall, then re-evaluating the reconfigured design is recommended. In some cases the need to plan for multiple evaluations may be more apparent; others are dependent on the findings of preceding evaluations.



GUIDING PRINCIPLE 2

The mock-up evaluation should be thoroughly planned to maximize effectiveness.

The scope of the evaluation should be outlined during pre-design (during or just after functional programming). It should include evaluation objectives, time and costs required to build and evaluate a mock-up, and identify which phase within the design stage the evaluation should occur. The evaluation should occur before finalizing design decisions that the evaluation is intended to inform.

DESIGNING AND BUILDING A MOCK-UP

Determining the location to build a mock-up is important and should consider a variety of factors. The mock-up can be built within existing facilities, within the shell of a new facility, or even off site. Co-ordinating and transporting users who will participate in the simulations becomes much easier and efficient when the mock-up is built within an existing facility from which users will be recruited. Using the shell of a new facility may make it easier to have physical space available to house the mock-up; however, construction hazards, timelines, and the risks associated with having individuals on an active construction site should be considered. Offsite facilities, such as a simulation centre or a warehouse, may be useful when users come from various geographic locations, or when space within an existing or new shell facility is unavailable. Other uses for the mock-up, such as a venue for design team meetings, should also be considered.

Mock-up fidelity, or the degree to which a mock-up is completed, can vary significantly. Levels of fidelity for physical mock-ups include simple, detailed, and live (or functional) mock-ups.³¹ Real or mock-up furniture and equipment can be used within the mock-up. If real equipment is not included in the mock-up, this will limit the scope of the potential findings and likely exclude, for example, equipment usability and manoeuvrability. Clinical users or a task analysis (described later, page 21), should be consulted to develop a comprehensive list of items to be included in the mock-up. The list should be cross-referenced with the scenarios to ensure, at a minimum, that all supplies and equipment (real or mock-ups) used in the scenarios are present.

Although mock-up fidelity may be affected by cost and time requirements, it is important that it aligns with the appropriate design phase (see Table 3) and the evaluation objectives. For example, if one objective is to assess the size of the room, including walls, it may not be necessary to include a ceiling or functioning lights, and furthermore the evaluation should occur during schematic design before finalizing decisions regarding room size. If, however, the location of a call bell is included in the evaluation scope, the planned placement of the call bell needs to be identified in the mock-up and used in a scenario enactment. The placement of fixtures is determined during the design development phase, and as such, evaluating placement should occur during design development to inform this decision. Similarly, if the evaluation includes assessment of the visibility of a patient monitor, then the mock-up and scenario needs to include a monitor with displayed information, which can even be a matter of printing information on a sheet of paper that is then taped onto a plywood monitor. Other equipment or items, which may block visibility of the monitor, also need to be included. If visibility of the monitor is found to be problematic, solutions would likely involve repositioning or relocating the monitor (and associated data and electrical outlets), relocating objects blocking visibility of the monitor, or moving the work area of individuals viewing the monitor. Solutions involving the placement of data and electrical outlets, and potentially relocating objects blocking visibility, need to be addressed during the design development phase. Some solutions, however, could be incorporated later in the design process to enhance visibility, such as adjusting monitor height, or using adjustable mounts, which could be addressed during construction/commissioning.

TABLE 3: Mock-up fidelity most applicable for each design phase

Design phase	Recommended mock-up fidelity
Schematic design	Simple mock-up
Design development	Detailed mock-up
Construction/commissioning	Live (functional) mock-up



GUIDING PRINCIPLE 3

Building of the mock-up should align with evaluation timing and objectives.

The degree to which a mock-up is completed (mock-up fidelity) can vary significantly. The mock-up should be built to an appropriate level of fidelity to enable testing of evaluation objectives during the appropriate design phase.

SIMPLE MOCK-UPS

Description: Simple mock-ups can be as basic as using tape to indicate the location of walls and cardboard boxes to indicate equipment or cabinet locations (see Figure 4^{iv}). Although economical with respect to time and dollars to build, some simple mock-ups do not provide the same physical constraints as a real room. That is, participants and equipment can move beyond tape lines and through ‘walls’ during scenario enactments, which can make evaluation and analysis less precise, require more effort, and in the end be increasingly challenging to interpret. Another common approach is to construct walls with plywood or foam-core (see Figure 5^{iv}). This approach more accurately assesses a specific room size or configuration. Real or mock-up furniture and equipment can be used to fill the space.

An alternative is to not have the wall locations indicated as part of the mock-up and measure how much space is used during scenario enactments in the absence of physical limits; this is known as a functional space experiment and has been successfully used by Hignett and colleagues.¹² This technique then defines the minimum-sized rectangle to encompass the flow of users during scenario enactments.

Uses: Simple mock-ups are most useful for evaluations early in the design process to evaluate space requirements because room size and configuration can be adjusted in both the mock-up and design plans. They can also be useful to help design teams from prematurely agreeing on a design because it is easy to provide several different alternatives using simple mock-ups.

When to use: Schematic design.

DETAILED MOCK-UPS

Description: Detailed mock-ups are finished to a greater degree compared with simple mock-ups and may include flooring, a ceiling, furniture, light fixtures, the headwall with electrical and gas outlets, and functioning millwork, as well as other details (see Figure 6^{iv, v}). Vendors are often involved in the supply and installation of larger pieces of equipment.

Uses: These are particularly useful to examine more detailed aspects of the design, such as headwall configurations, architectural details, space and workflow efficiency, and usability issues with the design or placement of equipment. Detailed mock-ups can also be used for staff orientation, training, or fundraising efforts.

When to use: Design development.

^{iv} This example reflects project work that was completed by the Alberta Health Services Human Factors team.

^v This example reflects project work that was completed by the University of Calgary and W21C Human Factors teams.

LIVE (FUNCTIONAL) MOCK-UPS

Description: Live mock-ups are fully functional rooms where actual patient care could (and might) occur (see Figure 7^{iv,v}). These typically involve renovating a room on a functioning unit before a major renovation or use of a room after construction as part of commissioning.

Uses: These provide an opportunity to support operational commissioning through staff orientation and training, test processes and communication channels, and assess how the room is set up and whether items are conveniently located. Live mock-ups can also be used to evaluate design changes resulting from previous mock-up evaluations. If actual patient care is being provided within the space, such as when renovating a room for a pilot test, data can be collected over time. Data can include those related to patient safety, such as adverse events (i.e., infections and patient falls) as well as patient and staff outcomes (i.e., length of stay and workplace injuries). Data from neighbouring rooms or units can also be used for comparison.

When to use: Construction/commissioning.

FIGURE 4: SIMPLE (TAPED) mock-ups used for simulation-based evaluation

Medical Day Unit Pod and Systemic Preparation Room⁴¹

Facility: Grande Prairie Regional Hospital, Grande Prairie, Alberta.

Location: Off-site in Queen Elizabeth II Hospital.



Description: Walls, millwork, curtains, and doors were marked out using tape on the floor. Furniture, equipment, and supplies came from the hospital. Where real equipment could not be obtained, equivalently sized items were used. Outlet locations were not identified.

Cost to build: \$880 for both spaces.

FIGURE 5: SIMPLE (CONSTRUCTED) mock-ups used for simulation-based evaluation

Designated Assisted Living Resident Room²⁹

Facility: To inform *Design Guidelines for Continuing Care Facilities in Alberta*.⁵¹

Location: Off-site warehouse, Spruce Grove, Alberta.



Description: Walls constructed with wood studs and drywall. Cabinets, fridge, and wardrobes constructed with wood but not made to be opened. Plumbing fixtures installed but not functional. Furniture and equipment supplied by local facility and vendors. The locations of outlets were indicated by the covers.

Cost to build: \$22,000 (initially built to be 30 m² and was enlarged to 32 m²).

Cardiac Hybrid Operating Room³⁴

Facility: Mazankowski Alberta Heart Institute, Edmonton, Alberta

Location: On-site, within planned space.



Description: Walls and counters constructed with steel studs and foam core. Cabinets outlined with tape on floor. Ceiling-mounted equipment (fully adjustable), surgical table, and computers constructed with wood. Equipment and supplies from hospital. Outlet locations were not identified.

Cost to build: \$25,000. Equipment mock-ups (i.e., articulating arms, surgical table) reused for multiple mock-ups.

FIGURE 6: DETAILED mock-ups used for simulation-based evaluation

Intensive Care Unit Patient Room¹⁰

Facility: Foothills Medical Centre, Calgary, Alberta.

Location: On-site in neighbouring building.



Description: Walls, doors, cabinets, and counters fully finished. Lighting and call bell installed and operable. Articulating arms installed. Equipment supplied by hospital. Gas, data, and electrical outlets installed but not connected.

Cost to build: \$158,000.

Emergency Department Exam Room³⁹

Facility: South Health Campus, Calgary, Alberta.

Location: On-site in neighbouring building (former shipping and receiving area).



Description: Walls, doors, cabinets, and counters fully finished. Lighting installed and operable. Equipment supplied by hospital. Gas, data, and electrical outlets installed but not connected.

Cost to build: \$153,000 for four mock-up patient rooms (Acute Care Unit, Intensive Care Unit, Emergency Department, Out-patient). \$47,000 of equipment reused during construction of actual room.

FIGURE 7: LIVE (FUNCTIONAL) mock-ups used for simulation-based evaluation

Interventional Trauma Operating Room^{14, 35}

Facility: Foothills Medical Centre, Calgary, Alberta.

Location: Built and commissioned room.



Description: Fully built room tested as part of operational commissioning with high-fidelity simulator.

Cost to build: \$6 million (full room build cost).⁵²

EMS Ambulance Patient Compartment³⁸

Facility: Safety concept ambulance design.

Location: Simulation testing conducted throughout the province.



Description: Operable ambulance, equipped with patient simulator and eye movement tracking device.

Cost: One ambulance out of service for seven months.

SIMULATION ROLES AND RESPONSIBILITIES

Preparing for and conducting a simulation-based mock-up evaluation requires extensive collaboration among diverse stakeholder groups. The National Interprofessional Competency Framework describes competency domains required for effective interprofessional collaboration.⁵³ To enhance role clarity, the roles and responsibilities for each person involved should be clearly defined. This includes identifying who will be responsible for evaluation design, staging the mock-up, data collection, and data analysis as well as who will participate in the scenario enactments. In some cases, multiple roles will be carried out by a single individual; at other times a team of individuals will support a lead person for a particular role. The tasks required before, during, and after the scenario enactments that should be assigned are listed (see Appendix 1) and described in the following sections. A review of internal expertise available, such as expertise in human factors or equivalent, will need to be considered to identify if individuals external to the organization should join the evaluation team. Performing a dry run (or pilot test) can help to clarify roles and ensure all required equipment and supplies are present.



GUIDING PRINCIPLE 4

Roles and responsibilities for those involved in the evaluation should be clearly defined.

This includes identifying who will be responsible for evaluation design, staging the mock-up, data collection, and data analysis as well as who will participate in the scenario enactments. Availability of expertise (e.g., human factors) should be assessed to identify if individuals external to the organization are needed.

SIMULATION PREPARATION

Creating simulation scenarios

Simulation scenarios (see Appendix 2 for template) are detailed descriptions of the clinical and/or non-clinical tasks to be performed by representative users (including patients and families) while interacting with the mock-up of the built environment. The design of a scenario is important because it has an effect on what can be discovered as part of the evaluation. For this reason, it is important that the tasks selected reflect those that are the most frequent, urgent, and challenging tasks to be performed in the space, while also testing the evaluation objectives listed in the evaluation scope. Challenging circumstances might include the need to accommodate the maximum number of staff while ensuring continual access to medical equipment and supplies.

A human factors specialist can conduct a *task analysis*^{vi} to assist in developing appropriate scenarios, which will result in a detailed understanding of how the tasks are performed in the space, as well as the equipment and supplies used (which should also be included in the mock-up).

^{vi} Task analysis can be described as the process of learning about ordinary users by observing them in action to understand in detail how they perform their tasks and achieve their intended goals.⁵⁴

Creating simulation scenarios – continued

Details to consider:

- A task analysis helps to identify and select the most appropriate tasks for the simulation scenarios. It is typically accomplished through systematic observations of users interacting with a space, its environment, equipment, and related work processes. They should be conducted by an individual with expertise in human factors.
- Information from the task analysis should be complemented with information from other sources, including the functional program, design requirements of the room, user focus groups, as well as design team questions or concerns to be addressed. Safety reporting data and user interviews can also be used to identify the essential and safety-critical tasks, as well as contributing factors to adverse events (e.g., distractions, interruptions, multi-tasking, etc.) to be incorporated into the scenarios.
- The number of tasks and the number of scenario enactments selected for the evaluation will depend on the evaluation scope and range of tasks typically performed in the space. In some situations, the same scenario may be enacted more than once. This may be, for example, to test design or process alternatives, to increase staff engagement in situations where knowledge and tasks are expected to be learned based on experience using the room, to obtain a higher level of accuracy or precision in the results, and/or to allow for statistical analysis. The number of scenario enactments used to evaluate the mock-ups listed in Table 1 ranged from two to five enactments, with an average of four.
- The number of tasks and scenario enactments planned will affect the time required to enact scenarios, number of debriefing sessions, time required of participants and observers, as well as the volume of information to be analyzed.
- It is important that the tasks selected result in reasonable time requirements for all individuals involved. Typically, one full day (or two half days) are dedicated to conducting the simulations. Half the time is used for performing scenario enactments and half (although often more) for structured debriefing to guide participant reflections.
- Depending on how long it takes to perform the selected tasks, the number of scenario enactments may be limited by the amount of time available.
- Representative users should provide feedback on draft versions of the scenarios with respect to realism and the degree to which they represent actual tasks expected to be performed in the space. Specific start and end points of the scenario should be identified.

One person (or sometimes a team) should be responsible for creating the simulation scenarios through collaboration with stakeholder groups representing the various users of the space; this person is the lead. The lead could be a human factors specialist, simulation consultant, healthcare practitioner with appropriate medical content expertise, or some combination. This person(s) will select appropriate tasks to be included in the scenarios, identify roles required to enact the scenarios, and determine required equipment and supplies.



GUIDING PRINCIPLE 5

The simulation scenarios that are created and enacted should test the evaluation objectives.

Evaluating a mock-up involves selecting frequent, urgent, and challenging tasks to create simulation scenarios that will test predetermined evaluation objectives. The scenarios are enacted by users of the space within the mock-up, which includes needed supplies and equipment (real or mock-ups).

Ethics and consent

Any project that uses information about or collected from individuals should go through an ethics review process to ensure participants are respected and protected. An ethics review process is used to identify and mitigate risks to participants in how information is collected and used in the project. For quality improvement and evaluation projects an ethics review process can usually be accomplished by the project team and does not require review by a Research Ethics Board unless local policies require it. Projects where there may be significant risks to individuals will benefit from a review by someone outside the project team with knowledge of ethical issues and mitigation strategies in that context. A pRoject Ethics Community Consensus Initiative (ARECCI) has developed a process and supporting tools that project teams can use to complete an ethics review for a non-research project.⁵⁵

Details to consider:

- Participants should be informed about the nature of the evaluation, their role in the evaluation, how information will be used, and that they may withdraw participation at any time without consequence.
- Participants should also be told how their information will be used and be reassured that no personally identifying information will be revealed.
- It is recommended that participants be informed before scenario enactment so that alternate participants can be found if some choose not to continue.
- Participants may benefit from receiving both written (e.g., a short frequently asked questions sheet) and verbal information about the evaluation process. The least amount of personal information relevant to the evaluation should be collected. Avoid collecting personal identifiers (e.g., name, contact information) if possible.
- When participants can be identified through photos or videos used in the evaluation, written consent is strongly recommended. Consent to take and use photos and videos must clearly articulate how the images will be used (e.g., data analysis, presentation, publication, etc.). Obtaining consent after the evaluation for new uses of the photos and videos can be difficult and time consuming.
- Distributing, collecting, and tracking consent forms for all those who observe or participate in the scenario enactments should be managed by at least one person (although more assistance may be required).

Recruiting participants

A listing of roles required to enact the scenarios is used to recruit individuals (and potentially backups) to participate in the scenario enactments. The person responsible for recruiting participants should be familiar with the typical characteristics of the roles involved in the scenarios, and also with the knowledge and experience levels of those individuals who might participate in the enactments. Those selected to participate ideally are the actual planned users (or equivalent) of the space. For example, a trauma surgeon would enact the role of a trauma surgeon. When the scenarios involve providing patient care, the simulated patient can be a mannequin, patient simulator (with vital signs, clinical signs and symptoms controlled by a computer), or confederates (patient and family advisors, members of the public, or actual patients).

Details to consider:

- Individuals should not participate in roles that do not match their job titles. Furthermore, those selected to participate in the scenario enactments should have had no prior involvement in the design process.
- Ideally each scenario enactment should have different individuals participating. In other words, the same participants should not participate in multiple scenarios. This is to best represent the breadth of approaches possible between individuals while performing their roles. Challenges recruiting different people for each scenario enactment may preclude this as a viable option. Additionally, users' level of experience should be considered when selecting participants as this affects user expectations and potentially performance. Select a range of users to include novice users with little or no experience/knowledge, occasional users with some previous experience, and expert users.⁵⁶
- Recruiting individuals may require back-filling their actual positions on the day of the scenario enactments.
- Special consideration should be given to selecting individuals to participate as patient and family members. Selection should be based on how closely they represent typical patients who will receive care in that space. Various tasks (e.g., performing CPR) may require the use of a mannequin or patient simulator for some or all scenario enactments.

Staging the mock-up

Equipment and supplies are needed that will make the mock-up environment as realistic as possible. Essential equipment and supplies will be listed with the written scenario scripts and in the task analysis (if conducted). Realism in the mock-up overall will enhance the scenario enactments and influence both the interactions and perceptions of those involved in the simulations. For example, device placement, movement, and use can be affected by the presence and length of attached lines and tubes. Furthermore, the presence of tubes, lines and electrical cables restricts the access and movement of people and equipment in tight spaces, which is another important design consideration. Where possible, real equipment and supplies should be used; however, using mock-up equipment with cardboard or printed screen shots for images on computer screens may be necessary. When equipment mock-ups are used, tubes, lines and electrical cables should be included.

Training participants

Training in advance of the simulations should be provided for any new processes or equipment with which participants may be unfamiliar. This will enhance accuracy in the way in which people interact with the equipment and environment to allow for a more accurate assessment of the evaluation objectives. Vendors may be best able to provide just-in-time training for some equipment or devices. Clinical educators or other staff members should provide training for new or altered processes.

Setting up an observation room

Permitting and encouraging stakeholders, particularly design team members, to observe the scenario enactments allows them to observe first-hand the issues that emerged during the scenario enactments, and can therefore accelerate decision-making and minimize the time required to make design changes.

Details to consider:

- Other than the simulation participants (as required by the scenario scripts), only the simulation director and individual(s) taking photos and videos should be present in the mock-up during scenario enactments. Any additional observers in the mock-up during the enactments would affect work flow and use of the space.
- Streaming live video feeds of the scenario enactments into an adjacent observation area is essential to minimize any distraction caused by observers. In some cases, observers can watch through a window into the mock-up space.

ENACTING SIMULATION SCENARIOS

Providing pre-briefing and scenario enactment instructions

Participants are provided instructions and a pre-briefing just before each scenario enactment (see Appendix 3 for sample script). The pre-briefing in part is used to create a psychologically safe environment where participants feel comfortable providing open and honest feedback and to augment their understanding of what is most relevant or critical with respect to the evaluation objectives. The script generally outlines background information, such as the purpose of the evaluation and an introduction to the space, tasks included in the scenario, roles and consent. The script also reinforces that the focus of the evaluation is on the design of the space, and not on individual performance. The person responsible for the pre-briefing and scenario instructions needs to be familiar with the scenarios, evaluation objectives, and methods.

Simulation participants might be asked to verbalize their thoughts as they enact the scenarios; this is called a *think-aloud protocol*.⁵⁷ In group settings, this is sometimes referred to as constructive interaction. This enables simulation participants to provide feedback mid-scenario as they encounter difficulties and reduces reliance on human memory when gathering feedback during the debriefing sessions after each scenario enactment. With this approach, instructions should be provided to participants before each scenario enactment, including what types of thoughts should be verbalized as well as a demonstration of how to think aloud. As an example, the person providing the pre-brief could play the role of a nurse hooking up an intravenous pump and verbalize a need to plug in the pump but that there are no conveniently located electrical outlets.

Directing the scenario enactments

Scenario enactments are guided by the simulation director. A person familiar with the scenarios and familiar with the clinical procedures and processes is typically responsible for this task. The simulation director ensures participants follow scenario scripts and that the scenario starts and ends as planned. The simulation director will also ensure that there are no observers in the room during scenario enactments.

Operating the patient simulator

If a high-fidelity patient simulator is used, the scenario will need to be programmed into the simulator and be operated by an individual with this expertise.

Taking photos and videos

Multiple video cameras can be used to catch all activities within the room and to allow for backup recordings in the event of unanticipated video equipment failures. Two or three people are usually responsible for taking photo, video, and audio recordings during the scenario enactments. Pictures will assist with both analysis and presenting findings (see Appendix 4 for suggestions). Video angles should capture full-room uses, while also capturing task-specific detailed usage data, particularly if video analysis is to be performed. This will require a variety of video cameras and mounts (see Appendix 5 for suggestions). Although there are high-tech alternatives to synchronizing multiple video cameras for data analysis and video editing/production, this can easily be done using a clapperboard or by simply clapping one's hands to provide a visual and audio marker, which ideally will be caught by all video cameras.

Recording audio

Digital audio recorders are increasingly advanced and inexpensive. These can be effectively used to record activities to supplement or as a backup to the video recordings. They can be mounted in the space or hung from the ceiling in an unobtrusive fashion. Lapel microphones on key participants can enhance the quality and accuracy of audio recordings.

DATA COLLECTION AND ANALYSIS

User feedback and analysis

The debriefing is intended to guide participant reflections of their experiences within the space after each scenario enactment is completed. When done skillfully, participants are guided through reflection of the tasks that occurred during the simulation in an organized and thoughtful way. Participants require debriefing to help organize this reflective process. Semi-structured interview questions are recommended for debriefing participants. This involves asking a predetermined list of questions while ensuring the flexibility to explore additional topics or questions as they arise. The architect can be a valuable addition to the participant debriefing sessions. Importantly, the architect's role is to provide information requested by participants and not to critique or refute feedback. Conversations with the architect prior to the debriefing can help set the expectation that the goal is to generate feedback and suggestions. Having the architect present during debriefing also can speed up the implementation of participant feedback as the architect hears their suggestions first-hand.

As part of the debriefing session, recommended design modifications can be captured on sticky notes and placed on mock-up walls, on a large floor plan, or in fact anywhere to indicate the location of proposed changes to the placement of fixtures, equipment, or supplies. Photos of various items can be used instead of sticky notes to make their placement more obvious to participants during the scenario enactments, and are easily movable. Recommended placement can be recorded after each debriefing session by photographing where items were placed. Placement can continue to be adjusted as needed after each scenario enactment and then be re-photographed. Asking for the rationale behind recommended placement of various items can help resolve discrepancies in opinions and identify relevant data that can be extracted from the videos if further support or analysis is needed.

While participants are debriefing, a separate session should be conducted with all observers. A separate session ensures the participants can be candid in their observations, uninfluenced by previous design decisions or by the rationale behind those decisions. This encourages thinking from a new perspective when identifying design issues or recommending design alternatives. Moreover, the observers are often supervisors of the participants; separate debriefing sessions further ensures participants feel comfortable providing open feedback.

Details to consider:

- Two debriefing facilitators are likely required: one to debrief the simulation participants and one to debrief the observers. The debriefing facilitators should be trained facilitators with experience and be comfortable facilitating debriefing sessions and focus groups.
- Having additional support to take notes on the feedback provided is helpful. One or both of the debriefing facilitators should have experience with qualitative analysis methods to be able to identify themes and summarize concerns from feedback provided while also extracting or identifying potential solutions to mitigate latent conditions or hazards.
- Additional feedback may be sought beyond the debriefing sessions. This may be useful, for example, if the scenarios include a large number of participants and there is a concern that not all opinions will be heard, to provide quantitative metrics with measurable data for statistical testing about user acceptance, or to further assess aspects of the evaluation (e.g., engagement, realism, etc.).

Video analysis

The amount of data collection and analysis will depend on a number of factors, including evaluation objectives, timelines, and availability of expertise and resources. Various data collection and analysis methods for consideration are described next. If video analysis is planned, an individual with experience using a variety of human factors methodologies should be engaged. Video analysis involves behavioural coding, analysis, and interpretation. Video editing experience will enhance the presentation of findings. In addition to analysis, this individual should be involved early enough in the design process to participate in discussions about the evaluation objectives to develop appropriate metrics to assess the objectives.

Video coding

Video recordings of each scenario enactment should be reviewed independently by two or more individuals, if possible, and coded with criterion to assess the evaluation objectives (see Appendix 6 for template). Common coding categories include adjustments made to equipment or monitors, bumps between people and/or equipment, excessive reaches, participants searching for equipment or supplies, line snags, visibility issues, and other usability issues encountered. Usability issues typically include participant verbalizations. The data from all coders are merged; duplicates are removed and discrepancies are resolved through consensus, typically after reviewing the video segment again.

How the data are used will depend on the evaluation objectives, but most commonly involve identifying patterns within pertinent categories. For example, if room size is being assessed, data pertaining to bumps (e.g., areas of congestion within the room), adjustments made to equipment or monitors (e.g., if things were frequently being moved out of the way), and verbalizations (e.g., comments pertaining to room size) may be relevant. In contrast, assessments of equipment or supply placement may focus more on bumps (e.g., frequency of bumps into a particular item), excessive reaches (e.g., to obtain or use the item), and searches for an item (e.g., which may indicate it is not intuitively or conveniently located).

Link analysis

Link analysis is used to identify and represents links (or relationships) to determine the nature, frequency, and importance of the links.^{58,59} The Center for Health Design recommends this tool for use during design to support decision-making at varying levels of design detail.⁶⁰ Link analysis involves using lines on a diagram (potentially an architectural drawing) to indicate where individuals involved in the scenario enactments moved from and to. Movement and room utilization is more accurately depicted by transcribing the actual paths of individuals onto an overhead view or architectural drawing of the space (see Figure 8). This may also be referred to as a spaghetti diagram. It typically involves watching the videos of the scenario enactments and drawing the links (lines) by hand or onto an electronic file (i.e., using Microsoft PowerPoint). Technology-based options, such as use of a real-time locating system, can automate the transcription process. Using a centrally located ceiling-mounted video camera, ideally with a wide-angle or fish-eye lens to capture the entire room, makes this step more efficient. Some scenarios or rooms may require multiple camera angles to fully capture all movements through the space. The resulting diagram can be used to visualize motion patterns, high-traffic areas of congestion, inefficiencies in staff workflow, and use of space by individuals and teams, or across teams.

FIGURE 8: Link analysis from a simulation based mock-up evaluation of an interventional trauma operating room (see also Figure 7).¹¹

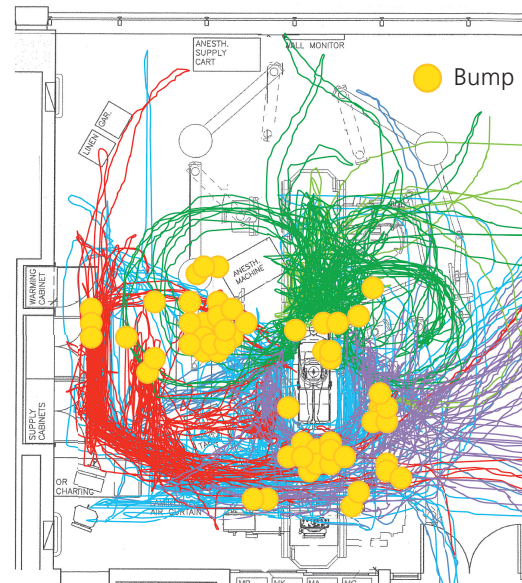
- | | | |
|---|--|---|
| ■ Surgeons/resident | ■ Anesthesiologist | ■ Circulating nurses |
| ■ Scrub nurses | ■ Anesthesia respiratory therapists | ■ Diagnostic imaging team |



Bump analysis

Conducting a bump analysis involves coding (generally as part of video coding as previously described) physical contact between two objects – people and/or equipment – that were not intended to make contact. Typically, this also includes coding what bumped into what and, potentially, whether each object was considered sterile. The location of each bump can be plotted onto an architectural drawing of the space and typically overlaid onto the link analysis diagram (see Figure 9). Combining data from a link and bump analysis shows interactions between people and equipment, and can identify areas of physical congestion and risk of contamination within sterile/clean areas. Data can be further examined to see which items are most frequently bumped to assess if design modifications could reduce the frequency of bumps.

FIGURE 9: Bump analysis added to link analysis.¹¹



GUIDING PRINCIPLE 6

Recommendations should be informed by evidence-based data from scenario enactments.

Evidence-based data, collected through user feedback and video analysis, is used to identify potential issues and successes with the planned design. The recommendations that are developed should address any identified issues.

DISSEMINATING FINDINGS AND RECOMMENDATIONS

Deliverables from a simulation-based mock-up evaluation often include a written report and/or presentation to the design team, accompanied by a listing of recommendations (see Appendix 7). Identified issues (and successes) with the planned design are often evidenced through pictures, video clips, user feedback, and/or video analysis data. After the findings are shared, the recommendations are reviewed by the design and evaluation teams to decide which recommendations will be implemented or require further investigation. The teams also assign responsibility for implementation and investigation as applicable.

Details to consider:

- The identity of participants in the pictures and videos should be protected by using editing software to blur faces unless permitted through explicit consent.
- The dissemination plan should also include sharing the results with simulation participants and stakeholder groups, and should consider broad distribution (program, site, provincial, national, or international presentations; journal publication; etc.) to promote knowledge transfer of lessons learned.

TRACKING AND EVALUATING IMPLEMENTED RECOMMENDATIONS

Tracking which recommendations were planned to be implemented, were actually implemented, and the effect they had provides many benefits. Initially it provides a mechanism for feedback to the evaluation and design teams. However, it also supports evidence-based design for use in future designs and generation of guidelines, as well as produces measurable outcomes to assess the overall value of conducting the simulation-based mock-up evaluation.

Details to consider:

- Collecting data to measure the performance of the built environment more globally, known as a post-occupancy evaluation, should be considered. This often includes the use of interviews, surveys, observations and/or physical measurements. Assessing the effect of implemented recommendations can be a sub component of the post-occupancy evaluation.
- Findings from the post-occupancy evaluation should also be disseminated.



Photo courtesy of Alberta Health Services

SUMMARY

The methodology described in this framework ensures simulation-based mock-up evaluations are guided by principles that have proven effectiveness in many healthcare settings in Alberta, and elsewhere, to bring about evidence-based design decisions. The meaningful participation of all user groups early in the design of healthcare environments can significantly improve the end result – creating safer, higher-quality spaces that enhance the overall patient experience as well as the experience for all users of the space. In addition, latent conditions which contribute to adverse

events for patients, families, and staff are removed, conflicts between equipment and people (i.e., bumps) are reduced, and functional and cost efficiencies are achieved. A simulation-based mock-up evaluation is one of many tools both within human factors and in other areas of expertise that can be used to evaluate the built environment. However, it is unique in that the evaluation process allows design teams to test, refine, and discover new design concepts as part of the design process based on anticipated processes and procedures. Furthermore, it facilitates meaningful engagement of planned users of the space into the design process. Other methods, such as tabletop exercises, usability testing, and post-occupancy evaluations, can be combined with mock-up evaluations and with other areas of expertise, including infection prevention and control, process improvement, occupational health and safety, and ergonomics to evaluate and improve design. Engaging all appropriate stakeholders and experts in a collaborative process improves design outcomes and ultimately patient care.

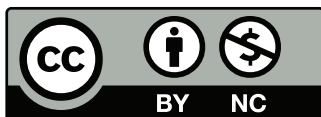
SIMULATION-BASED MOCK-UP EVALUATION APPENDICES

The appendices are intended to assist in conducting simulation-based mock-up evaluations. It is important to note, however, that the information and templates contained in the appendices will likely need to be modified on a project-by-project basis to best reflect the requirements of the design team and the specific evaluation objectives. The documents in the appendices can be downloaded from hqca.ca/humanfactors.

Appendix 1: Listing of evaluation tasks	32
Appendix 2: Simulation scenario template	33
Appendix 3: Sample pre-briefing script and instructions	34
Appendix 4: Photography suggestions	36
Appendix 5: Videography suggestions	37
Appendix 6: Data analysis spreadsheet template	38
Appendix 7: Recommendations template	40

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Please contact the Health Quality Council of Alberta for more information: info@hqca.ca, 403.297.8162.

APPENDIX 1: LIST OF EVALUATION TASKS

Simulation preparation

- Create simulation scenarios
- Obtain ethics approval and consent
- Recruit participants
- Stage the mock-up with furniture, equipment and supplies
- Train participants
- Set up an observation room

Enacting simulation scenarios

- Provide pre-briefing and scenario-enactment instructions
- Direct the scenario enactments
- Operate the patient simulator
- Take photos and videos

Data collection and analysis

- Debrief with scenario participants and observers for feedback and analysis
- Conduct video analysis
- Develop findings and recommendations

APPENDIX 2: SIMULATION SCENARIO TEMPLATE

SCENARIO *[INSERT #]*

SIMULATION-BASED MOCK-UP EVALUATION OF *[INSERT ROOM NAME]*

Date:

Background *[insert appropriate background information about the room and rationale for the evaluation]*

Stakeholders

Project sponsor: *[insert name and contact information]*

[list stakeholders, including the name of the group being represented and the name and contact information of the individual representing the group]

Scenario *[insert written description/overview of the scenario]*

Scenario tasks	Evaluation objectives	Notes
<ul style="list-style-type: none"> <i>[list tasks in chronological order]</i> 	<ul style="list-style-type: none"> <i>[list evaluation objectives associated with each task and how they will be evaluated]</i> 	<ul style="list-style-type: none"> <i>[for example confederate instructions to introduce a distraction]</i>
<ul style="list-style-type: none"> 	<ul style="list-style-type: none"> 	<ul style="list-style-type: none">

Scenario requirements

Location: *[insert address and directions]*

Participants: *[list all roles directly involved in this scenario and name of the individual enacting each role]*

Equipment required: *[list all equipment involved in this scenario and name of the individual responsible for bringing each piece of equipment]*

Supplies required: *[list all supplies involved in this scenario and name of the individual responsible for bringing each supply]*

Other requirements: *[includes room configuration requirements, make up/moulage needed, etc.]*

Pre-scenario training required *[list all training needed prior to enacting scenarios including training provided in-house or by vendors]*

Out of scope *[list things that will not be included in the evaluation scope]*

APPENDIX 3: SAMPLE PRE-BRIEFING SCRIPT AND INSTRUCTIONS

PRE-BRIEFING SCRIPT SIMULATION-BASED MOCK-UP EVALUATION OF

[INSERT ROOM NAME]

Date:

Welcome Participants *[Provide the same instructions for each scenario enactment]*

Thank-you Thank you for taking part in the *[insert room name]* simulation-based mock-up evaluation. Your participation in the mock-up evaluation will help inform the design of this room.

Safety briefing *[insert safety briefing information as applicable to both the mock-up room as well as the site where the mock-up is located. This will include site safety rules, known hazards such as tripping hazards from electrical cords, evacuation arrangement, locations of drinking water and sanitary facilities. If the mock-up is located within a construction site, this information may be presented by site management.]*

Introductions I would like everyone to introduce themselves.

Schedule You should have received a schedule and questionnaire upon arrival. Please return the completed questionnaire before you leave.

Consent forms

I hope everyone has reviewed and signed consent forms. As previously explained, one consent form shows that you give your permission to participate; the other form says that you agree to permit evaluators to take photos and videos during the scenario enactments and share them with *[list all uses]* to best communicate specific room design issues and recommendations. If you have not signed the consent forms, please come see me. These consent forms must be signed before anyone can participate.

Study Instructions

<i>Background</i>	The purpose of this simulation-based mock-up evaluation is to help inform the design of the new <i>[insert room name]</i> . <i>[Insert appropriate background information about the room and rationale for the evaluation]</i> .
Scenarios	As part of this evaluation, you will be asked to participate in a number of scenario enactments that are expected to commonly occur in this room. The focus of the study is NOT TO EVALUATE YOUR PERFORMANCE but on the adequacy and use of space within the room for the patient and healthcare professionals. Before enacting each scenario, the scenario will be read aloud and participants will be reminded if they miss any of the tasks in the scenario.
<i>Think aloud</i>	While enacting the scenario, we ask that you think aloud. When you think aloud, you state out loud what comes to mind as you enact your role. For example, if I were enacting the role of a nurse in the scenario and was hooking up an IV pump that needs to be plugged in, I might say that I need to plug in the pump and that there are no conveniently located electrical outlets. There are no right or wrong comments, so please speak freely. If you forget to state your thoughts out loud, I may occasionally prompt you to continue to do so.
<i>Debrief</i>	If you forget to mention something during a scenario, you will also be given an opportunity to have a reflective conversation through debriefing at the end of the each scenario. For those involved in the scenario, I will be conducting the debriefing. For those not directly involved in the scenario, <i>[insert name of debriefing facilitator]</i> will be conducting the debriefing session.
<i>Questions</i>	Before we start with the scenario enactments, does anyone have any questions?
<i>Thanks</i>	Once again, I'd like to thank each one of you and next we will discuss the scenario which will be enacted.

APPENDIX 4: PHOTOGRAPHY SUGGESTIONS

Photos to take

- Full room – aerial view (with no people)
- Full room – panoramic views (with no people)
- Room set-up before and after the scenario enactment
- All equipment, including close-ups of any interfaces
- All outlet configurations
- Post-it note placement (in the mock-up or on a floor plan) after each debriefing session
- Each participant (for identification when conducting link analysis, etc.)
- Ongoing photos during the scenario enactments

Camera equipment

- Digital camera(s)
- Extra batteries and battery charger(s)
- Memory card(s)
- Photo editing software
- Long electrical extension cords
- Tripod(s)

APPENDIX 5: VIDEOGRAPHY SUGGESTIONS

Video camera angles

- Full room – aerial view (ideally with one video camera, potentially with a fish eye lens, but may require multiple video cameras)
- Video camera focusing on each areas of use (i.e., medication preparation area, anesthetic area/head of the bed). Consider anticipated locations of people and equipment to minimize any obstructions they may cause given the planned video angles.

Recording test videos prior to the scenario enactments and reviewing them on a computer is important to ensure video camera placement will sufficiently capture all desired angles with acceptable video and audio qualities.

Video camera equipment

- Multiple video cameras
- Memory cards
- Wide angle lenses
- Batteries and chargers
- Long electrical extension cords
- Lapel microphones
- Suction mounts
- Clamp mounts
- Flexible and fixed extension arms for mounts
- Tripods
- Computer capable of editing large video files
- Video analysis software (e.g., Microsoft Excel, NVivo, Noldus)
- Video editing software

APPENDIX 6: DATA ANALYSIS SPREADSHEET TEMPLATE

The data analysis spreadsheet is often customized to support analysis. For example, when the category of bump is selected, the evaluator may include additional columns in the spreadsheet to identify the 'bumper' and 'bumpee', and may also further specify if those objects were sterile or not. In some cases it may be helpful to number the bumps on the architectural drawing and in the spreadsheet to allow for cross-referencing.

ROOM *[INSERT ROOM NAME]*

SCENARIO *[INSERT SCENARIO # AND NAME]*

CAMERA	ELAPSED TIME	NOTES	CODER	CATEGORY	VIDEO COMMENT
C1: Aerial	00:00:00	SCENARIO START	<i>[initials]</i>	<i>[see below]</i>	
C2: Head of bed		<i>[insert description/observation]</i>			
C3: Surgical area	00:30:00	SCENARIO END			
C4: Foot of bed					

SAMPLE DATA ANALYSIS SPREADSHEET ENTRIES

C4: Foot of bed	00:03:24	Circulating nurse bumps head on ceiling mounted monitor while prepping back table with OR instruments	JS	Bump	good angle for highlight video
C4: Foot of bed	00:03:50	Nurse says there is lots of room at the end of the OR table to gown up	SB	Beneficial	
C4: Foot of bed	00:05:14	Circulating nurse must move the equipment carrier behind the anesthetic machine to make space for the case cart to be brought over	JS	Congestion	
C1: Aerial	00:05:38	Nurse suggests moving or rotating OR charting desk for more adaptable space use	SB	Suggestion	
C3: Surgical area	00:07:20	Anesthesia respiratory therapist squeezes between patient and IV pump	JS	Access	
C3: Surgical area	00:07:45	Nurse has difficulty removing arm extenders from OR table	JS	Usability	
C4: Foot of bed	00:07:55	Nurse trips on sponge bucket	SB	Tripping hazard	
C2: Head of bed	00:08:10	Anesthesiologist searches through 2 drawers of drug cart	SB	Searching	
C2: Head of bed	00:08:23	Anesthesiologist reaches over IV tubing to deliver medication in patient's arm to avoid walking around equipment	SB	Excessive reach	

SAMPLE DATA ANALYSIS SPREADSHEET ENTRIES

CAMERA	ELAPSED TIME	NOTES	CODER	CATEGORY	VIDEO COMMENT
C3: Surgical area	00:08:50	Anesthesiologist asks for the site rite (ultrasound) for the 2nd time	JS	Communication	
C1: Aerial	00:40:48	DI tech moves monitor to bring in C-ARM	JS	Adjustment	
C3: Surgical area	00:41:03	Lines resting on C-arm are pulled when rotating C-arm	SB	Line snag	
C3: Surgical area	00:43:15	Nurse lifts bed drapes to watch lines while moving the C-ARM	JS	Visibility	

Category	Definition
Adjustment	Adjustment made to equipment or monitor.
Access	Equipment needed that is not easily accessible.
Beneficial	Positive design feature noted by participant or evaluator.
Bump	Physical contact between two objects (people and/or equipment) that were not intended to make contact.
Communication	Unsuccessful attempt to communicate (i.e., lack of response, demonstrated confusion, repeated instructions, multiple simultaneous communications, or disruptions due to environmental noise).
Congestion	An object (person or equipment) is in the way.
Excessive reach	Accessing something beyond one's 'reach envelope', which is the length of an extended arm.
Line snag	Unintentionally applying force to a line (IV) being used as part of patient care.
Cord/cable snag	Unintentionally applying force to a cord (for power supply or patient monitoring) being used as part of patient care.
Searching	The location of a supply or equipment is unknown to an individual needing it.
Suggestion	Verbalized comment or room design/equipment observation.
Tripping hazard	Object (people or equipment) required to move over another object, cord, or line.
Usability	Difficulty using a computerized technology, equipment, packaging, or data entry devices.
Visibility	Needing to see something (i.e., patient, monitor, equipment, etc.) that is not in view of the individual needing to see it.

APPENDIX 7: RECOMMENDATIONS TEMPLATE

SIMULATION-BASED MOCK-UP EVALUATION OF
[INSERT ROOM NAME] RECOMMENDATIONS

Last Updated: DD MMM YYYY	Priority	Capital Cost	Operating Cost	Decision to Proceed	Operational Owner	Comments
<i>[insert name to cluster recommendation by area or recommendation type i.e., Bathroom]</i>						
1 <i>[insert recommendation]</i>	High	High	High	Yes - to be incorporated		[include recommendation modifications, added details, alternative solutions, plans to follow-up or implementation progress]
2 <i>[insert recommendation]</i>	Medium	Medium	Medium	Yes - already incorporated		
3 <i>[insert recommendation]</i>	Low	Low	Low	Yes - but modified		
<i>[insert name to cluster recommendation by area or recommendation type i.e., Articulating Arm]</i>						
4 <i>[insert recommendation]</i>		N/A	N/A	No		
<i>[insert name to cluster recommendation by area or recommendation type i.e., Communication]</i>						
5 <i>[insert recommendation]</i>				Follow-up		

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