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Designing for Safe and Resilient Performance: bridging theory and practice

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What is safety?

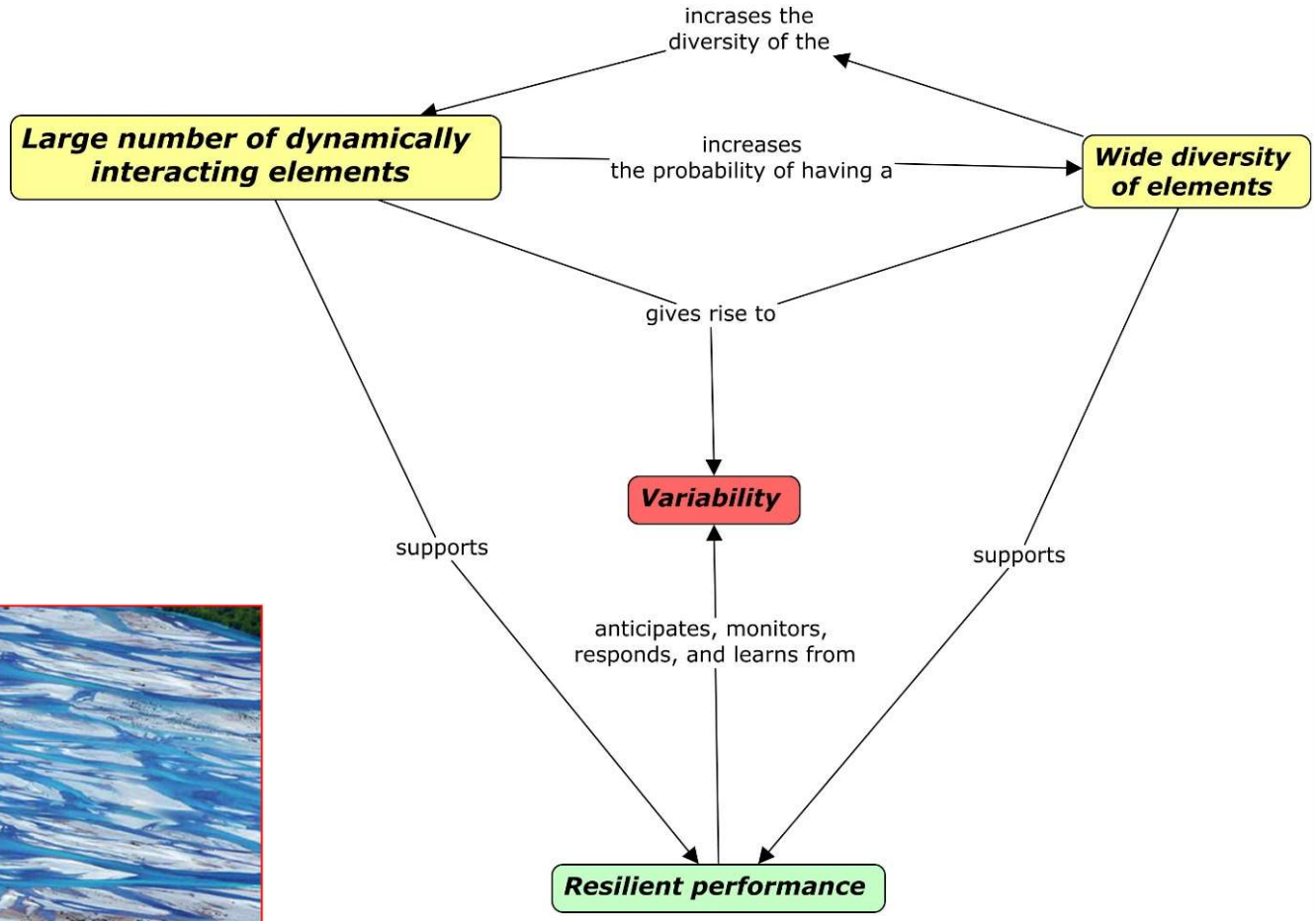
- **Safety I**
  - Absence of harm to people and damage to physical assets
  - Measured through accident rates, costs of accidents, fines,…

- **Safety II**
  - Presence of activities, resources, and ***adaptive capacity***
  - Measured through proactive indicators. E.g., quality and quantity of training, investments, ***buffers/slack resources***,…

SAFETY = SAFETY I + SAFETY II

Hollnagel, E. (2018). *Safety-I and safety-II: the past and future of safety management*. CRC press.

Safety-II and complexity

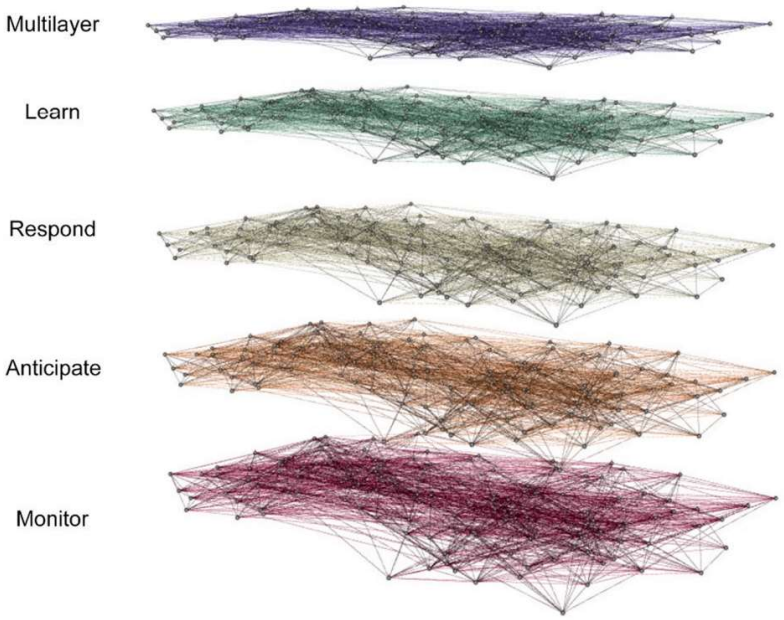


Righi, A.; Saurin, T.A. (2015) Complex Socio-Technical Systems: Characterization and Management Guidelines. Applied Ergonomics 50, 19–30.

What is resilience?

Resilient **performance** describes how well a system adjusts its functioning **before**, **during**, or **after** changes and disturbances, sustaining operations under **expected** and **unexpected** conditions

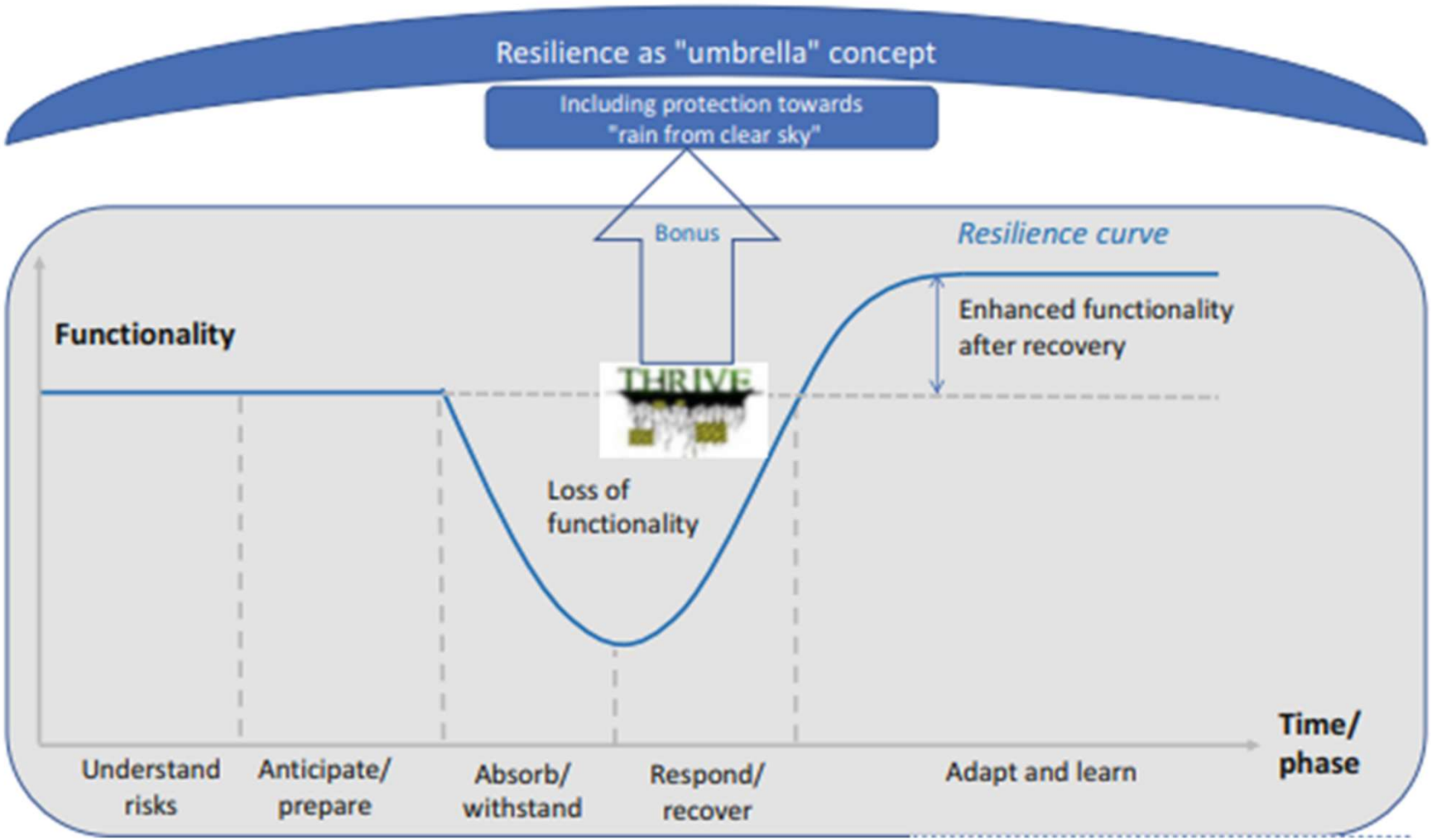
(Erik Hollnagel)



4 potentials of resilient systems

Monitor
Anticipate
Respond
Learn

Resilience as an umbrella concept



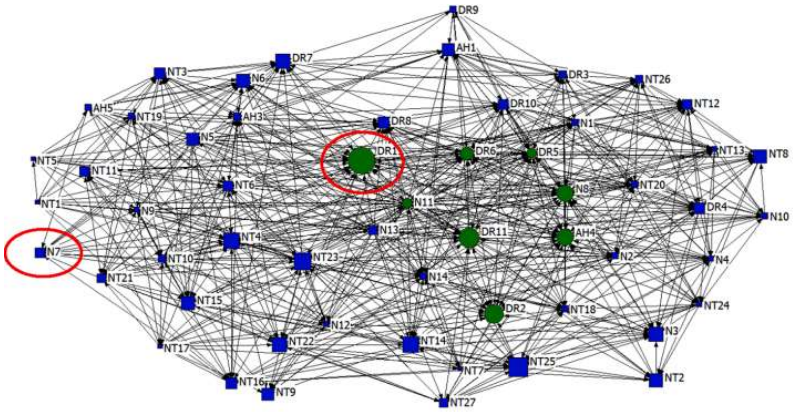
Adapted from Grøtan, T.O., Antonsen, S. and Haavik, T.K., 2022. Cyber Resilience: A Pre-Understanding for an Abductive Research Agenda. In: Matos, F.; Selig, P.; Henriqson, E. (Eds.), *Resilience in a Digital Age: global challenges in organisations and society,* pp. 205-229, Springer, Cham.

Resilience and safety

SAFETY I: safety benefits resilience because a resilient system must survive to accidents

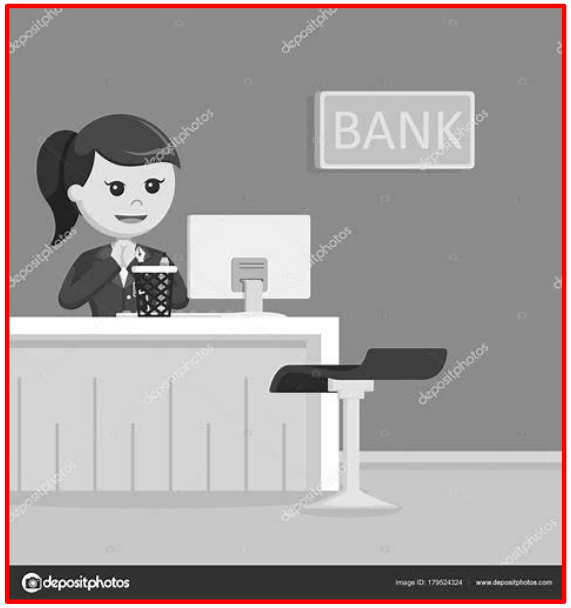
SAFETY II: resilience benefits safety because adaptive capacity helps cope with dynamic risks

WARNING: resilience can occur at the expense of workers health and safety. Thus, resilience and safety do not always go hand-in-hand

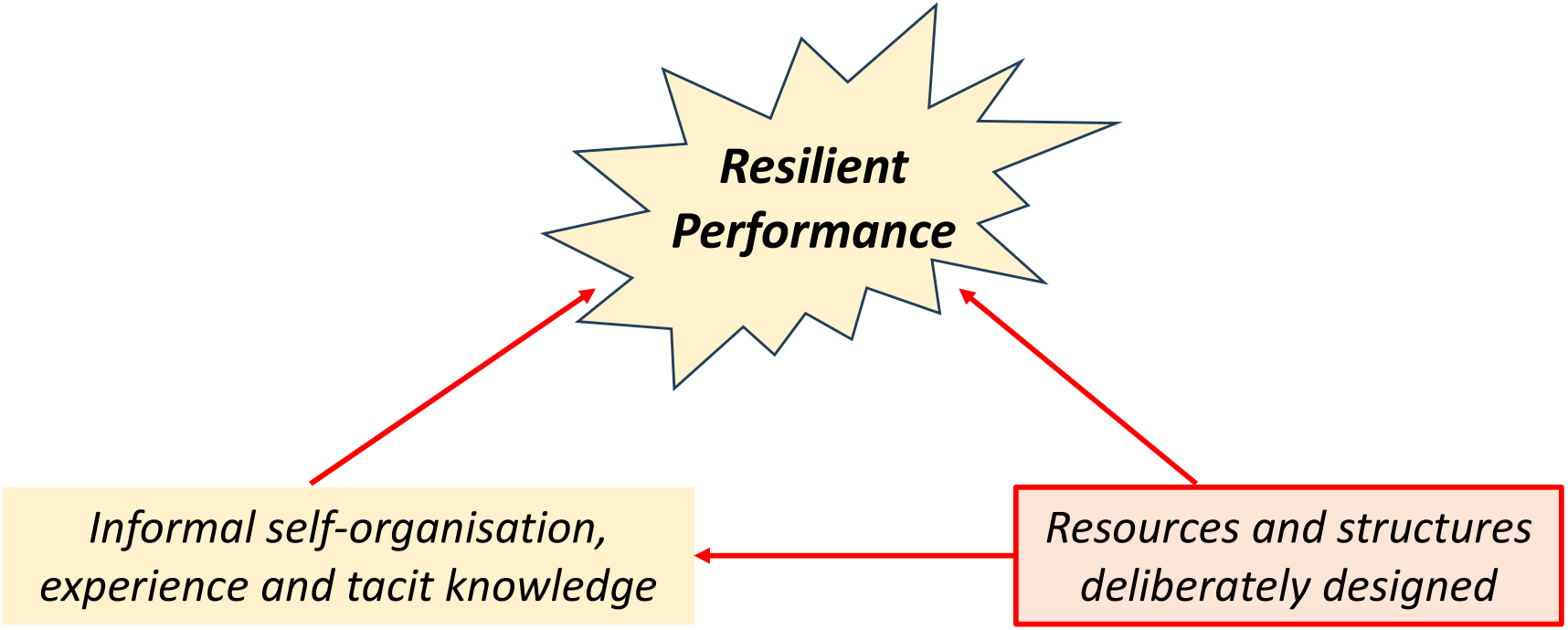


Terra, S. X., Saurin, T. A., Fogliatto, F. S., & de Magalhães, A. M. M. (2023). Burnout and network centrality as proxies for assessing the human cost of resilient performance. *Applied Ergonomics*, *108*, 103955.

What is the most resilient and safe design?



Design for Resilient Performance (DfRP)



The use of design principles to support integrated human, technical, and organisational adaptive capabilities


Applied Ergonomics 101 (2022) 103707

Contents lists available at ScienceDirect

Applied Ergonomics

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Design for resilient performance: Concept and principles

Claudia Maria Dias Guerra Disconzi *, Tarcisio Abreu Saurin


Applied Ergonomics 114 (2024) 104141

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Principles and practices of designing for resilient performance: An assessment framework

Claudia Maria Dias Guerra Disconzi [a], Tarcisio Abreu Saurin [b,*]

A knowledge framework of DfRP

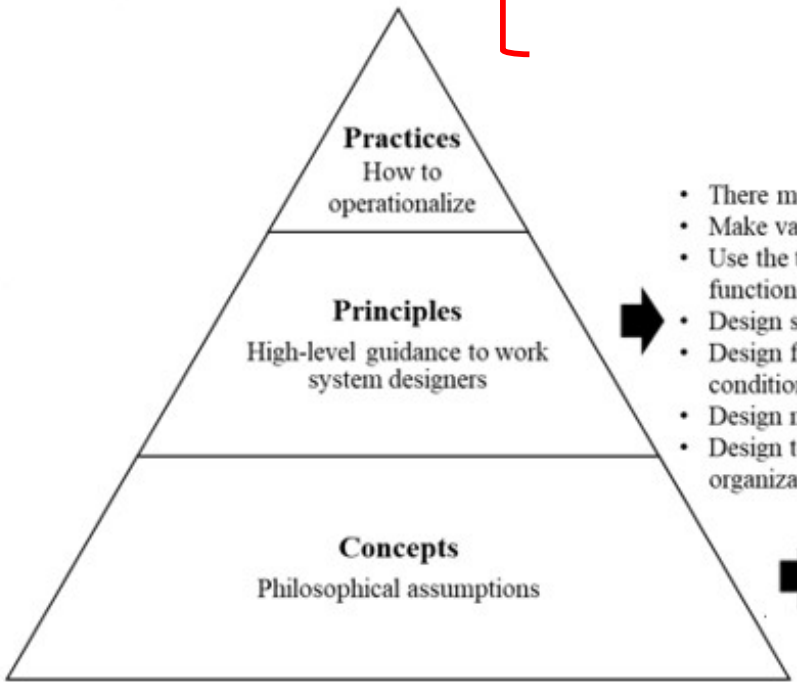
Tool box safety meetings

Pre-task safety planning

Production planning and control

Emergency response services

and others...



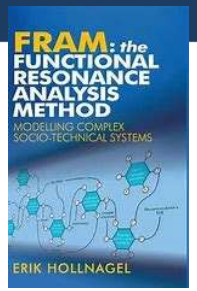
- There must be functional models of the system
- Make variations in performance visible
- Use the type of standardization that best fits the nature of the function
- Design slack resources and strategies
- Design for acceptable performance even under degraded conditions
- Design must involve leveraging diverse perspectives
- Design to support continuous learning at the individual and organizational level

- Resilience
- DfRP

Practices are designed managerial processes and tools that operationalize the principles, necessarily including a human component

Design principles

(1) Develop *models* of the system



(2) *Learning* at the individual and organisational level

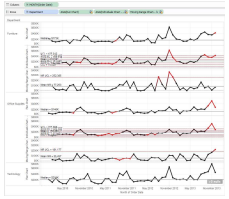
(3) Standardization that *best fits the nature of the function*

(4) *Slack* resources and strategies

(5) Acceptable performance under *degraded conditions*

(6) *Leverage diverse perspectives*

(7) *Variations in performance* visible



1

There must be models of the system

Functional model – Value Stream Mapping (VSM)

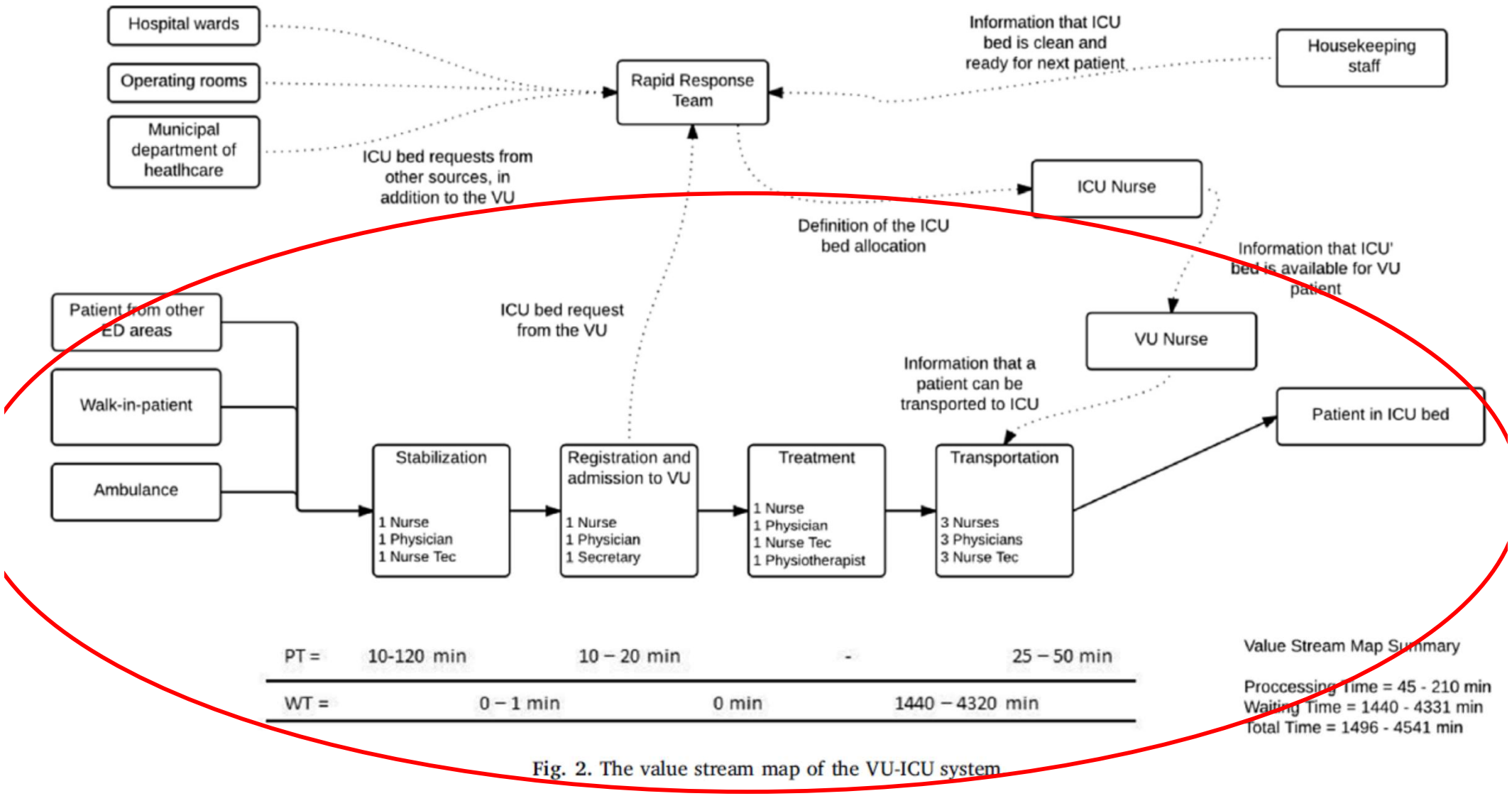
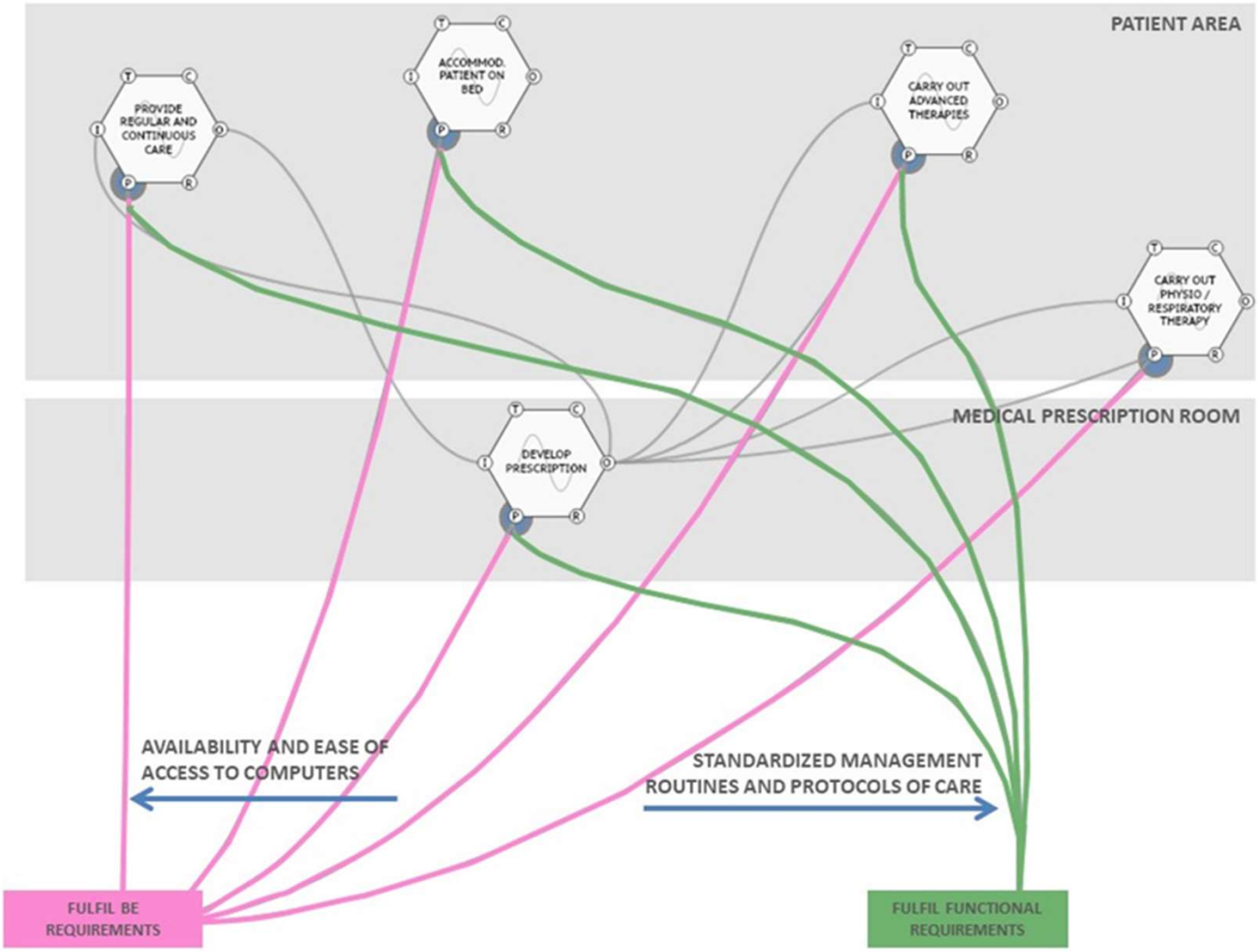
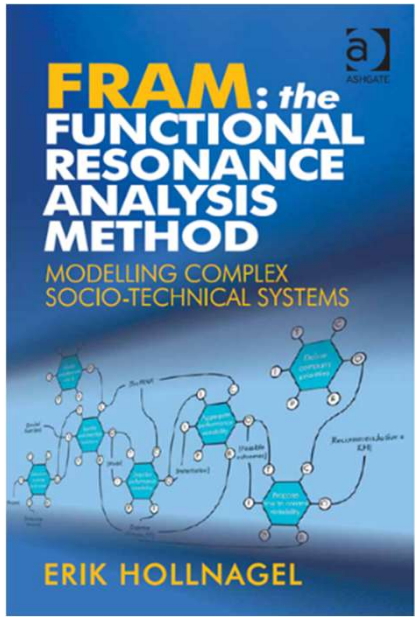


Fig. 2. The value stream map of the VU-ICU system

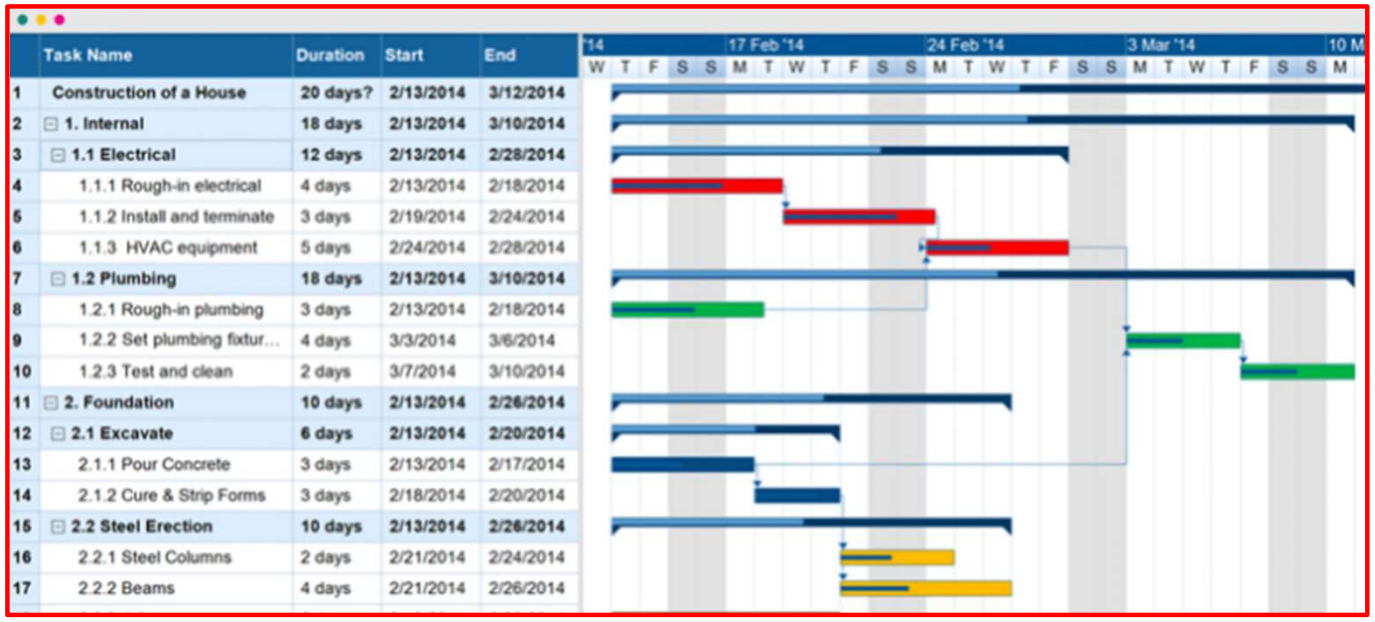
Functional model - FRAM





Ransolin, N., Saurin, T.A., Formoso, C.T., 2020. Integrated modelling of built environment and functional requirements: implications for resilience. *Applied Ergonomics*, *88*, p.103154.

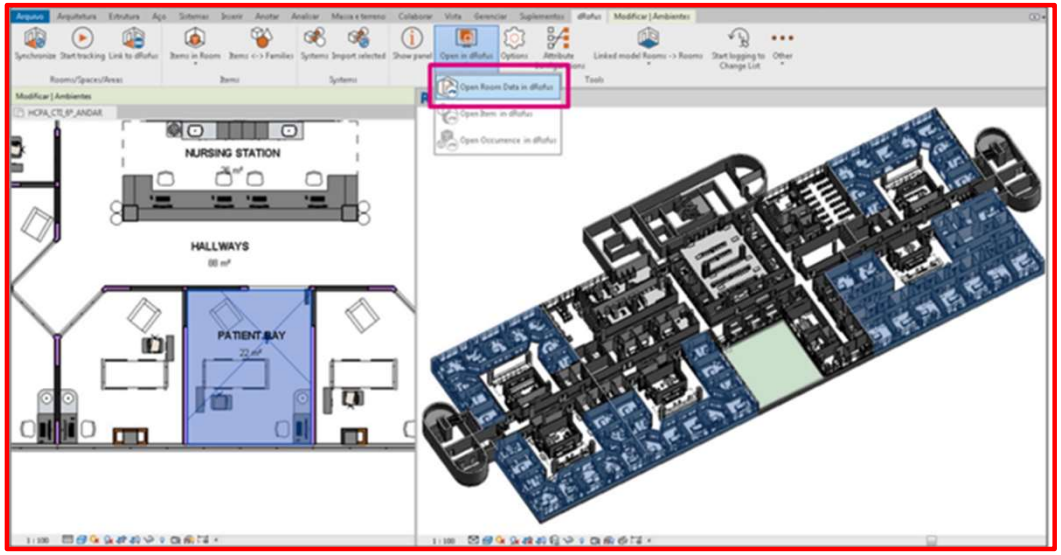
Other types of models

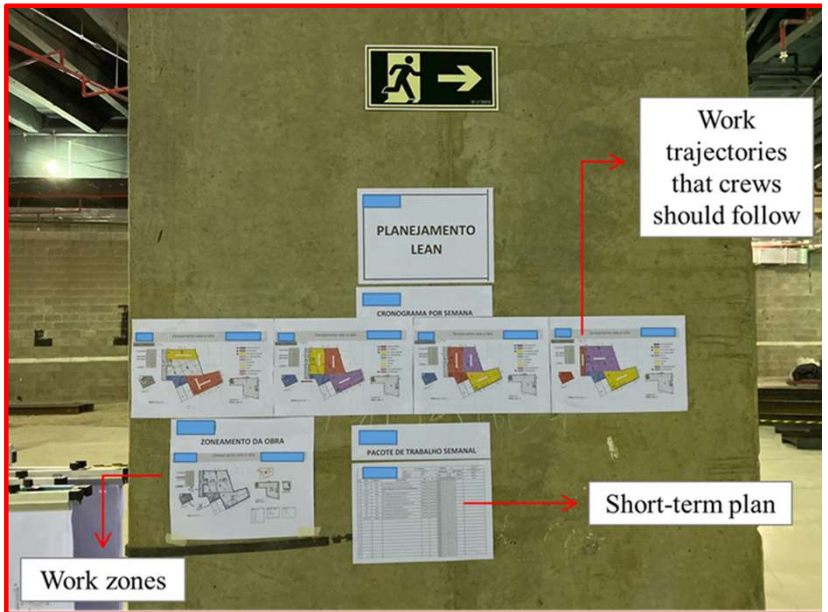


	Task Name	Duration	Start	End
1	Construction of a House	20 days?	2/13/2014	3/12/2014
2	1. Internal	18 days	2/13/2014	3/10/2014
3	1.1 Electrical	12 days	2/13/2014	2/28/2014
4	1.1.1 Rough-in electrical	4 days	2/13/2014	2/18/2014
5	1.1.2 Install and terminate	3 days	2/19/2014	2/24/2014
6	1.1.3 HVAC equipment	5 days	2/24/2014	2/28/2014
7	1.2 Plumbing	18 days	2/13/2014	3/10/2014
8	1.2.1 Rough-in plumbing	3 days	2/13/2014	2/18/2014
9	1.2.2 Set plumbing fixtur…	4 days	3/3/2014	3/6/2014
10	1.2.3 Test and clean	2 days	3/7/2014	3/10/2014
11	2. Foundation	10 days	2/13/2014	2/26/2014
12	2.1 Excavate	6 days	2/13/2014	2/20/2014
13	2.1.1 Pour Concrete	3 days	2/13/2014	2/17/2014
14	2.1.2 Cure & Strip Forms	3 days	2/18/2014	2/20/2014
15	2.2 Steel Erection	10 days	2/13/2014	2/26/2014
16	2.2.1 Steel Columns	2 days	2/21/2014	2/24/2014
17	2.2.2 Beams	4 days	2/21/2014	2/26/2014

These models serve different purposes and play complementary roles

Safety implications are not usually emphasized





2

Design to support continuous learning at the individual and organizational level

Learning from both what goes wrong and what goes well

Reflective meetings

- Resilient Performance Enhancement Toolkit (RPET)

- Hospital example (Nawal Khattabi, 2022, https://rhcs.se/wp-content/uploads/2022/08/16-august2022-6-nkhattabi.pdf)

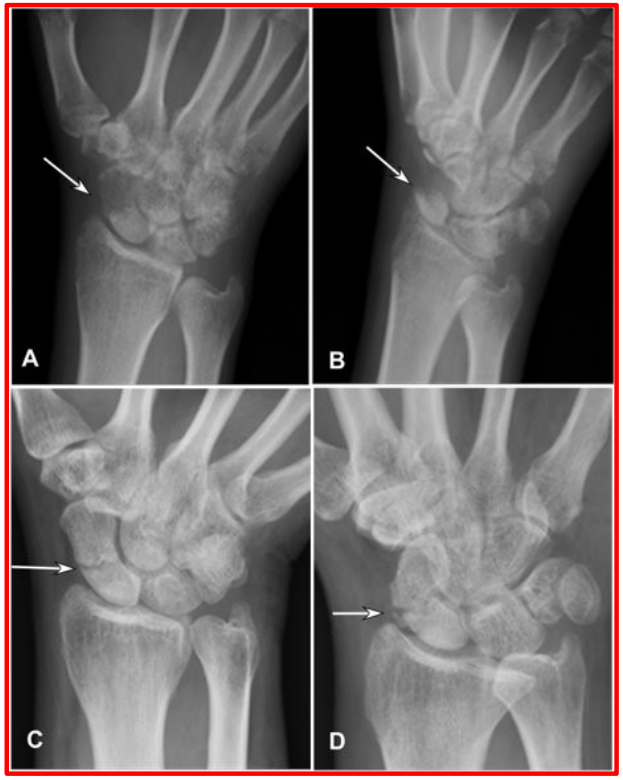
Daily meetings at the end of the shift to discuss what went well and what went wrong

Patient with wrist trauma

Traditional X-ray view did not detect the injury

Technician tested an alternative view and it detected the trauma

This new view has been used as a standardized procedure



For a RPET application in construction, see Martins, J.B., Carim Jr, G., Saurin, T.A. and Costella, M.F., 2022. Integrating Safety-I and Safety-II: Learning from failure and success in construction sites. *Safety Science*, *148*, p.105672.

Development of resilience skills

Resilience skills (RSs) support performance adjustment in order to work safely and efficiently during both expected and unexpected situations

- RSs are *typically social and cognitive*
  - Hazard identification, decision-making, communication,…
  - Conventional training usually focuses on procedural skills

Example: electricity distribution company

- Training did not account for the complexity of work-as-done

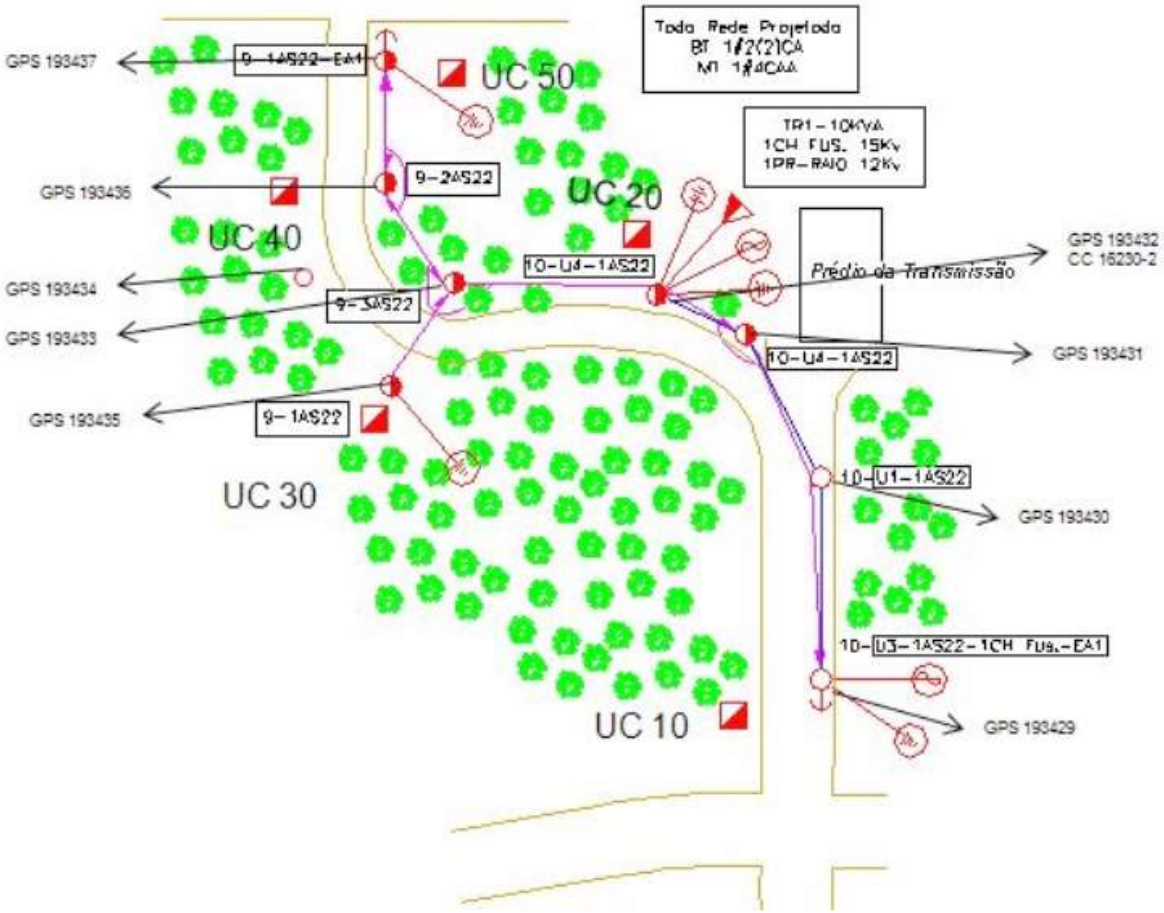
Saurin, T.A., Wachs, P., Righi, A.W. and Henriqson, E., 2014. The design of scenario-based training from the resilience engineering perspective: A study with grid electricians. *Accident Analysis & Prevention*, *68*, pp.30-41.

How were the resilience skills identified?

Data sources	Detail	Quantity
Observations	Training course	60 h
	Work-as-done	20 h
Documents	Accident investigation reports	61 documents
	Incident reports	57 documents
	List of competences, skills, and attitutes	1 document
	Training course syllabus	1 document
Interviews	***Critical Decisions Method***	***13 interviews***
	Focus group 1	24 company represent.
	Focus group 2	2 experts

Cognitive Task Analysis

Scenario-Based-Training



Typical training session

- Theoretical background (1 h)

- Briefing (10 min)
- Simulation (40 min – 2 h)
- Debriefing (1 h – 1.5 h)

3

Use the type of standardization that best fits the nature of the function

There are different types of procedures

- Goal-oriented procedures
- Process-oriented procedures
- Action-oriented procedures

Move to this direction as complexity grows

Hale, A. and Borys, D., 2013. Working to rule or working safely? Part 2: The management of safety rules and procedures. Safety Science, 55, pp.222-231.

Wachs, P. and Saurin, T.A., 2018. Modelling interactions between procedures and resilience skills. Applied Ergonomics, 68, pp.328-337.

Joint design of procedures and training for resilience skills

- Case study of preparation and administration of medications in an emergency department

HOSPITAL DE CLÍNICAS PORTO ALEGRE RS

POP de Via oral - administração de medicamentos

Página 1/5

POP-GENF-0133

Local de execução
Unidade do paciente.
Resultados esperados
Administração correta e segura do medicamento.
Executor
Equipe de Enfermagem
Material
- Bandeja;
- Medicamento prescrito;
- Copo descartável 25 ml;
- Prescrição médica;
- Etiqueta;
- Caneta;
- Compressas;
- Álcool 70%.
- Seringa dosadora oral;
- Copo descartável 50 ml;
- Pistilo;
- Gral ;
- Ampola de água destilada 20 ml;
- Água potável.

Atividades

Are these specifications detailed enough?

- *"Check if the patient is allergic before administering the medication"*
- *"Observe adverse reactions of the patient, during and after drug administration"*
- *"Medications must be safely prepared and administered"*

- *If more detailed specification does not make sense*, these issues should be prioritized in training

Resilient procedures?

- Are the **goals of the activity** stated in the procedure?
- Are the **minimum inputs and preconditions** required to start the activity stated?
- Are there examples of **under / no specification** that should have been specified?
- Are there **work constraints** that can make it difficult to follow the procedure stated?
- Are there **over specifications**?

- Are the direct **relationships with other procedures** mentioned?

Scenario-Based-Training

- Design of training scenarios
  - Story, work constraints, resilience skills
  - Debriefing
  - Insights into work system and procedures redesign
    - **Table with information**

    on the dilution of medications

4

Designing slack resources and strategies

What is slack?

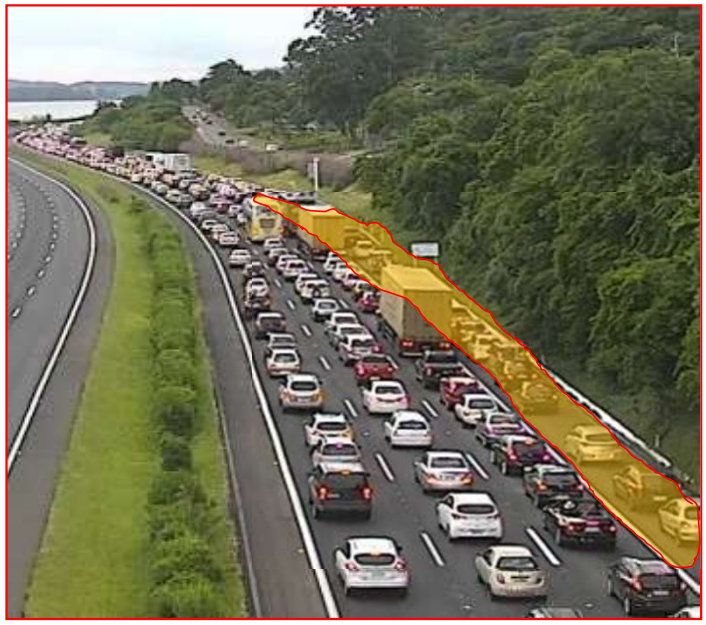
- Slack is a cushion of actual or potential *resources* which allows an organization to *adapt* successfully to internal or external *pressures* for adjustment (Bourgeois, 1981)

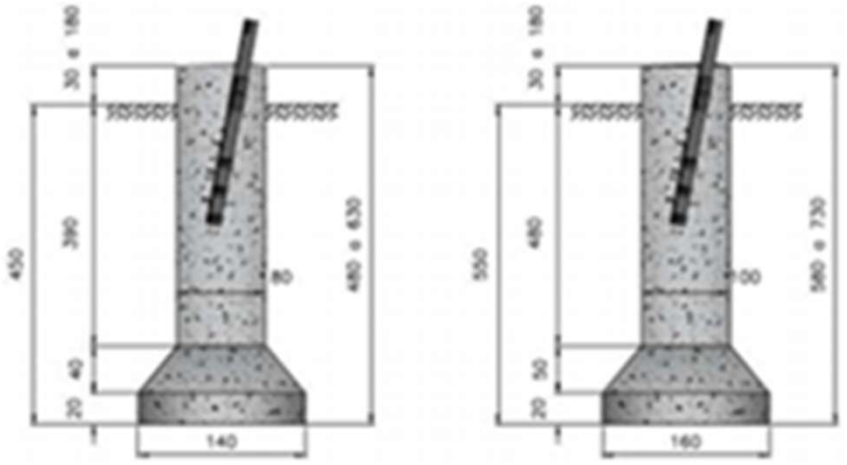
Variety of resources

People, materials, space, money, time, equipment, procedures,...

Bourgeois, J. (1981). On the measurement of organizational slack. *Academy Management Review*, 6(1): 29-39.

Examples of slack





Amaral 2015

Strategies: redundancies

- Resources provided in addition to the minimum necessary or more than one resource performing the same function
  - **Redundant procedures**: double-checks

  - **Active/hot**: redundant resource is involved in the task at hand

  - **Standby/cold**: redundant resource is not involved in the task

Rapid Response Teams (RRTs) – Example of resource on standby

✓Identification of ward patients whose condition is deteriorating, early notification to responders, rapid intervention and evaluation of the processes of care

Triggers for calling the RRT.

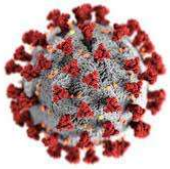
Clinical conditions		Triggers
	Airway	Need for intubation
	Breathing	Respiratory frequency <8 or >35 movements per minute Oxygen saturation <90%
	Blood circulation	Heart rate <40 or >140 beats per minute Systolic blood pressure <80 mmHg Systolic blood pressure between 80 and 90 mmHg and deterioration of the clinical condition
	State of consciousness	Decrease in Glasgow coma scale >2 points Repeated or prolonged seizure (>5 min)

Afferent arm (i.e., those who monitor the patients and call the RRT)

Efferent arm (e.g., those who respond to the call)

Strategies: margins of manoeuvre

- Defensive
  - Maintain local margins by restricting other units´ margins or borrowing margins from them
  - Ex: lockdowns during the pandemic, suspension of elective surgeries



- Autonomous
  - Creating margins via local reorganization or adaptation of resources
  - Ex: process improvement that frees up resources

- Coordinated
  - Resources that can be easily reallocated or repurposed
  - Ex: multifunctional workers and equipment

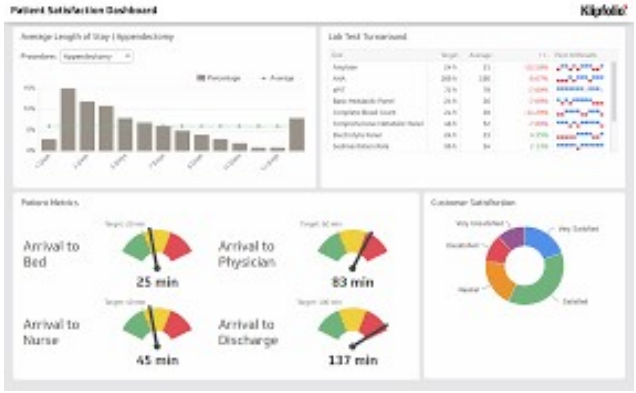
Stephens RJ, Woods DD, Branlat M, Wears RL. Colliding dilemmas: interactions of locally adaptive strategies in a hospital setting. Proceedings of the 4th REA Symposium, 2011. p 256 -262.

Strategies: inventories

- Raw materials
- Intermediate products
- Finished products

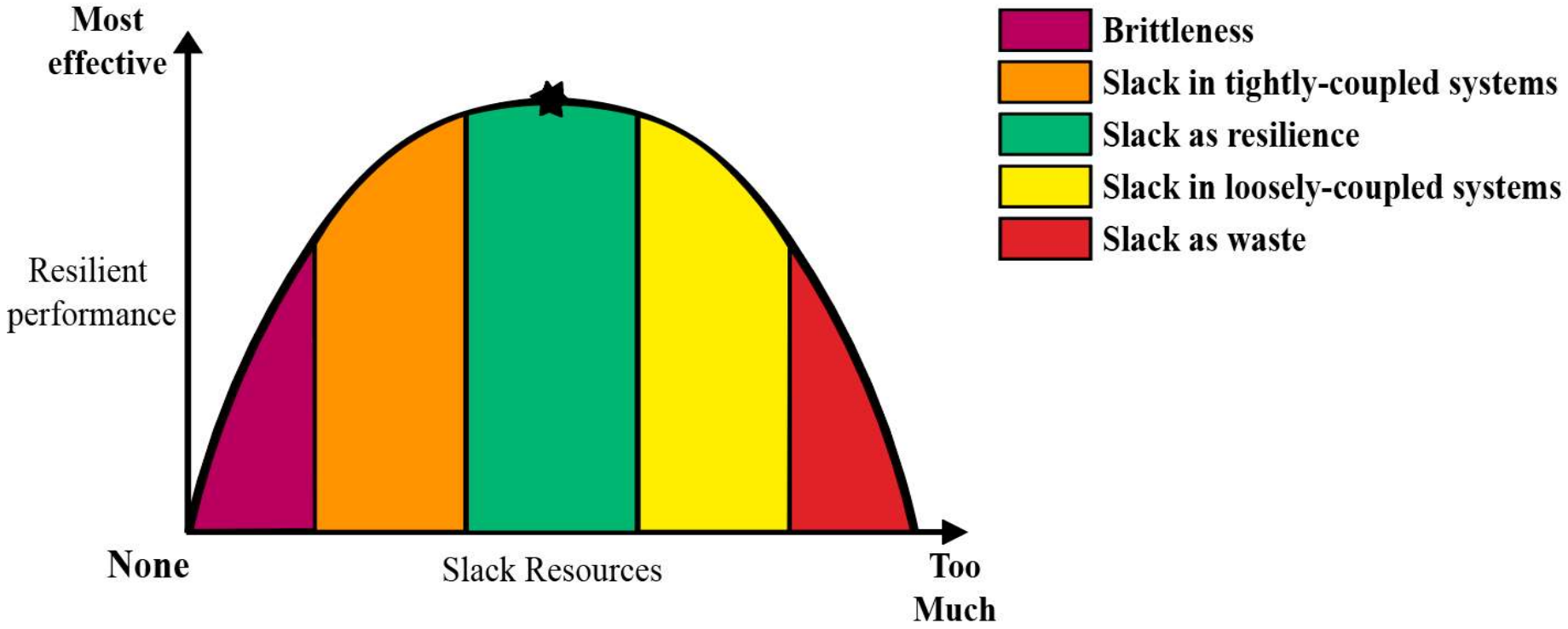
Taxonomy

- Nature of resources
- Strategy
- Designed vs. opportunistic
- Availability
- Visibility
- Durability
- Versatility
- Performance of the replacement
- Side-effects
- Legal requirement



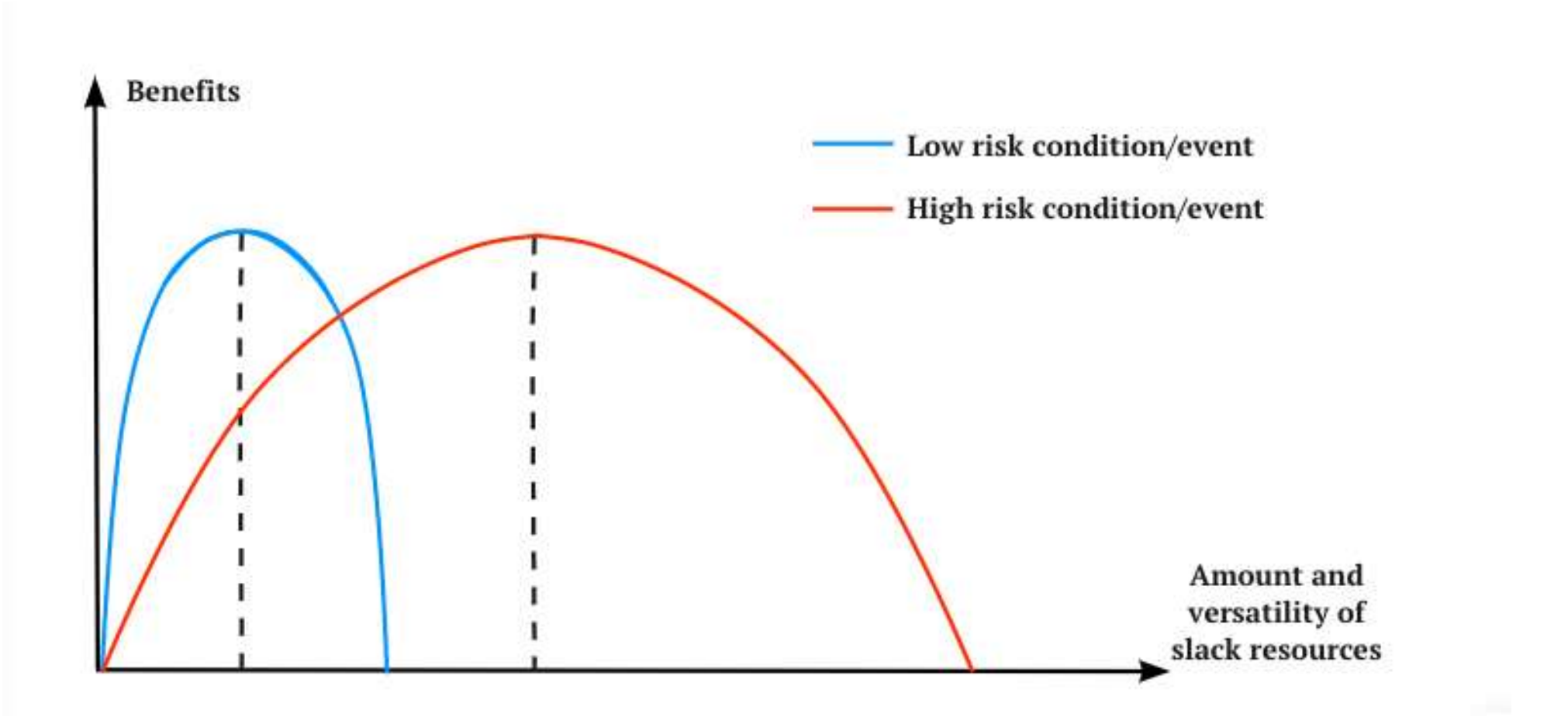
Saurin, T. A., Werle, N. J. B. (2017). A framework for the analysis of slack in socio-technical systems. Reliability Engineering & System Safety, 167, 439-451.

How much is enough?



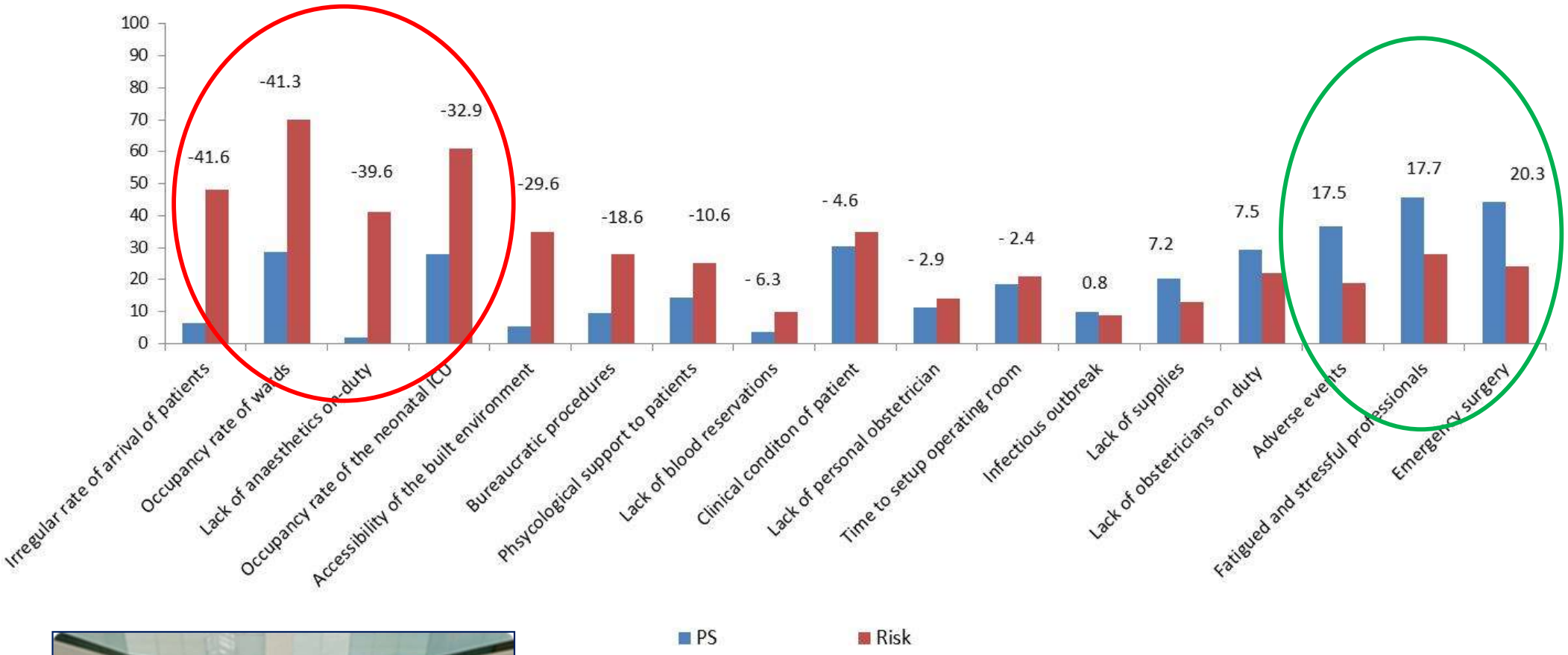
What counts as best can vary depending on the stakeholders´ perspective

It depends on risk



Role of non-technical factors (e.g., political pressures) on what counts as low / high risk

How much is enough?



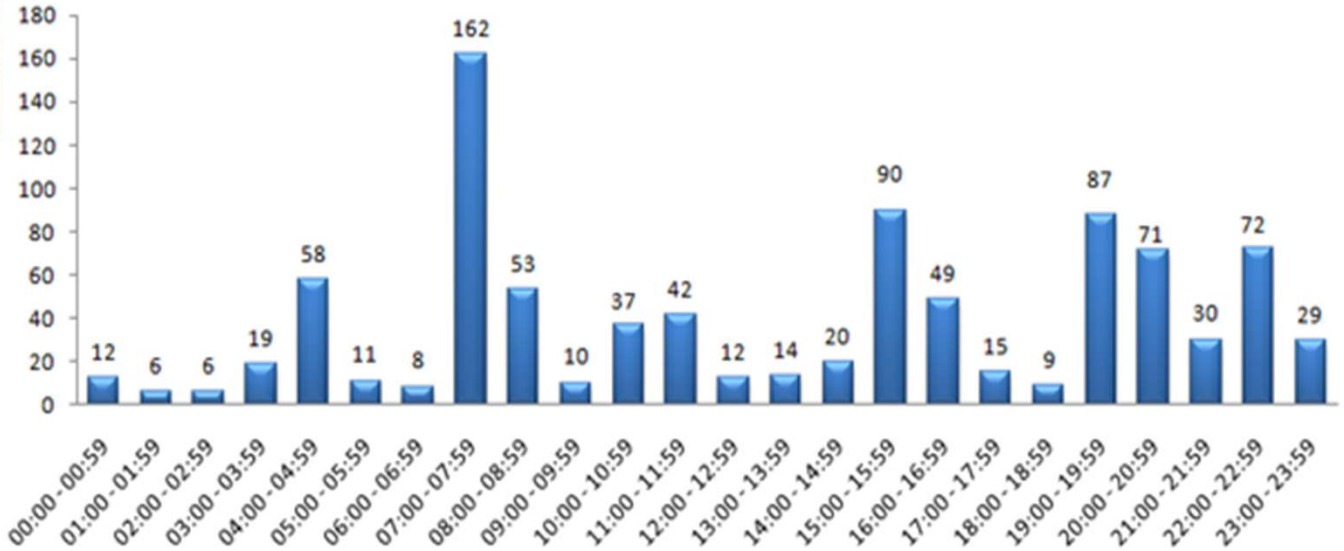
Hospital hired a full-time anesthetist e changed the composition of the committee that manages the blood bank

Saurin, T. A., Werle, N. J. B. (2017). A framework for the analysis of slack in socio-technical systems. Reliability Engineering & System Safety, 167, 439-451.

Too much slack can hide waste

- Two automatic dispensing cabinets were necessary due to the peak of demand at 8:00 am

Demand of medications during the day



Unintended consequences

Waste (e.g., unlevelled demand) should be removed before adding more resources – more complexity

Unintended consequences are less likely to occur if major wastes are reduced before adding slack resources

5

Designing for acceptable performance under degraded conditions

Particularly important for disaster management

Adapted areas for ICUs

Marczyk et al. BMC Health Services Research (2023) 23:579
https://doi.org/10.1186/s12913-023-09495-4

BMC Health Services Research

RESEARCH Open Access

Slack in the infrastructure of intensive care units: resilience management in the post-pandemic era

Other hospital units (e.g., recovery rooms, in-patient wards, emergency departments) could be designed to accommodate ICU patients

- Oxygen supply, electricity supply, air quality, size, etc.

Built environment climate resilience

6

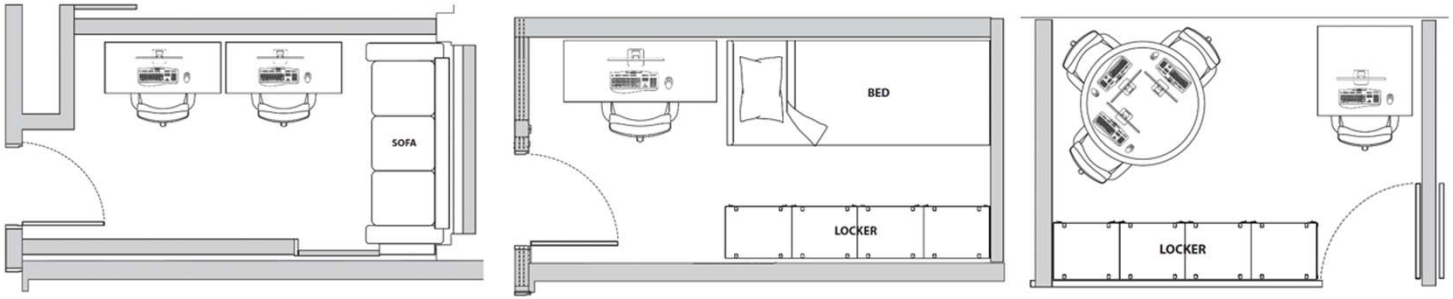
Design must involve leveraging diverse perspectives

Diversity of perspectives

- Take advantage of diversity to reduce uncertainty
- Requirements
  - Trust, low power differences, capable decision-makers
- Hard to implement under time pressure
- Collaboration costs

Workspace layout supportive of diverse perspectives

Before: teams in different rooms and floors



(a) Rapid Response Team (b) Medical On-Call Team (c) Nursing Supervision

(a) Rapid Response Team (b) Medical On-Call Team (c) Nursing Supervision

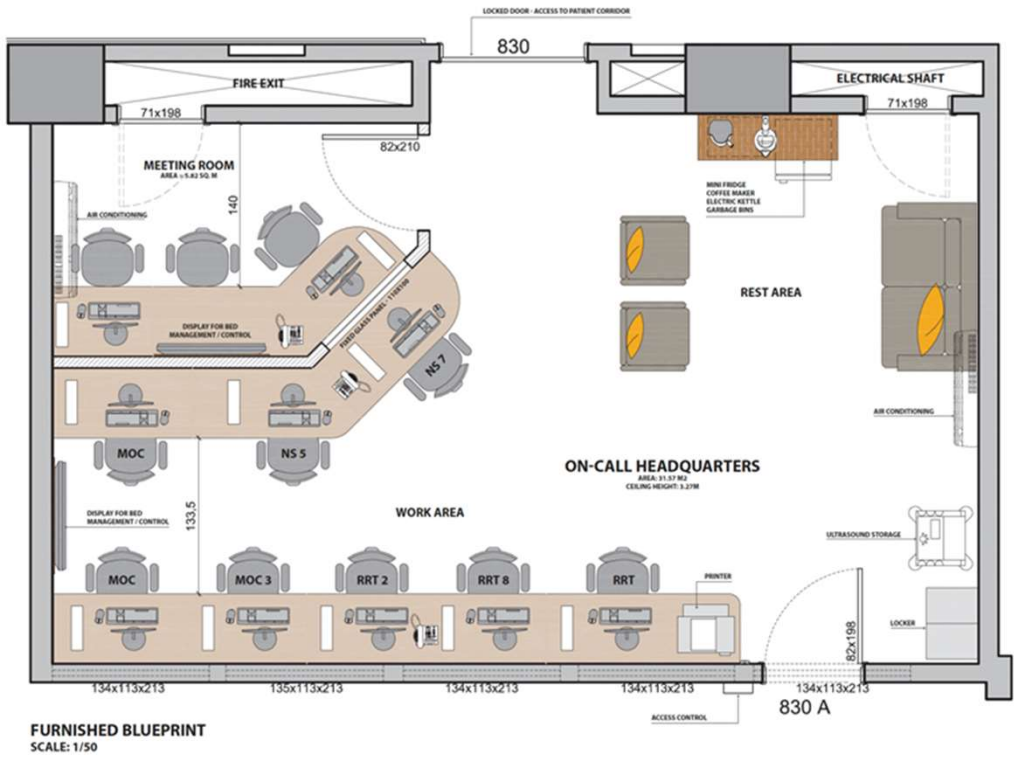
HERD: Health Environments Research & Design Journal
OnlineFirst

https://doi.org/10.1177/19375867241271435

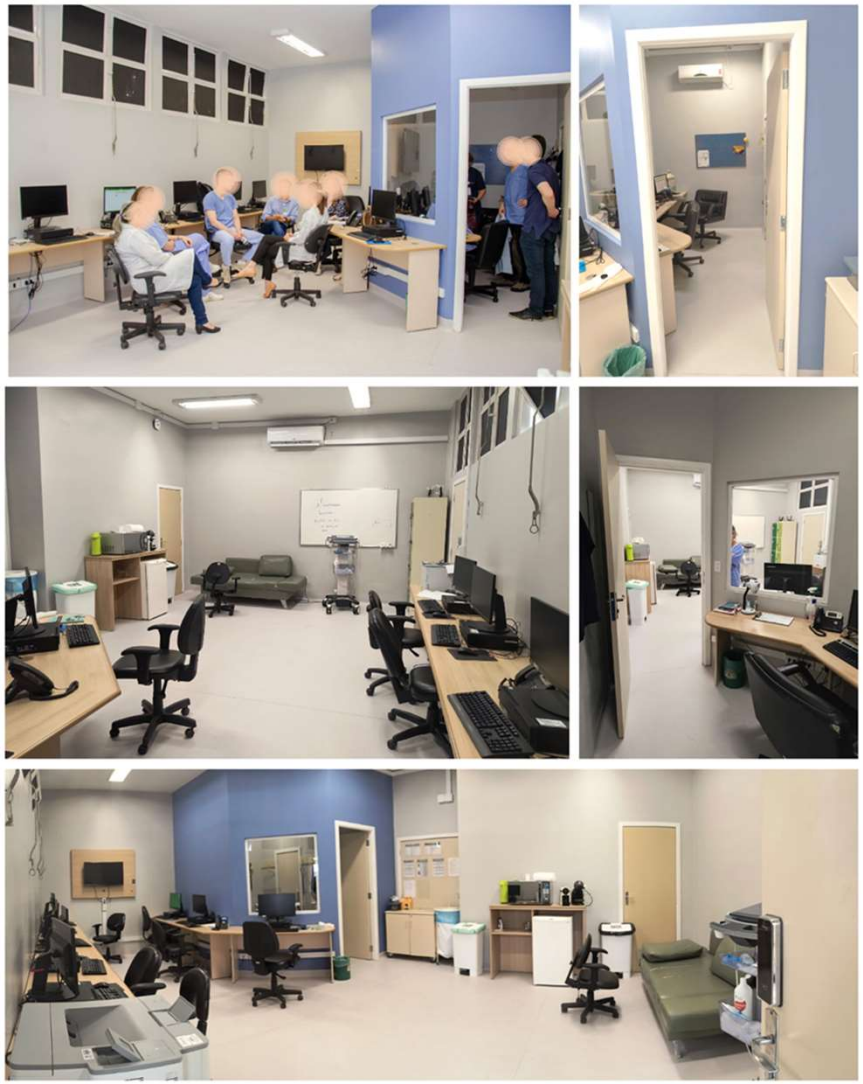
Sage Journals

Case Study

Workspace Layout for Resilient Performance using Social Network Analysis: A Case Study



After: shared workspace



Learning becomes easier, accounting for diverse perspectives

Time saved from seeking for colleagues becomes slack

Interactions between kaizen projects

Esc Anna Nery 2018;22(4):e20170402

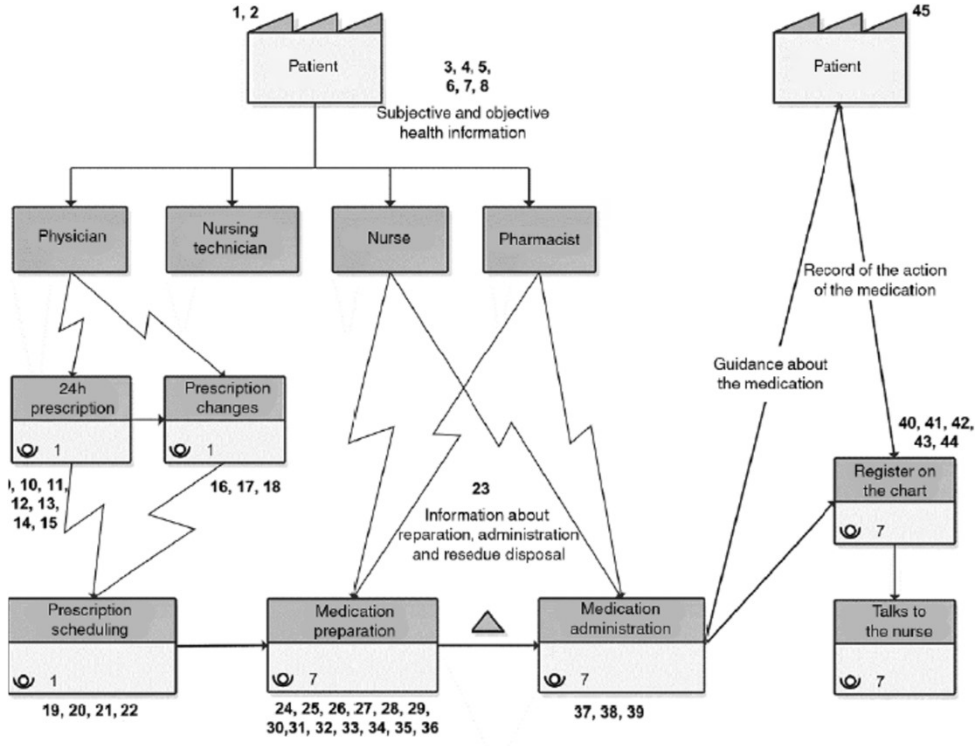
RESEARCH | PESQUISA

EEAN.edu.br

Analysis of the preparation and administration of medications in the hospital context based on Lean thinking

Análise do preparo e administração de medicamentos no contexto hospitalar com base no pensamento Lean

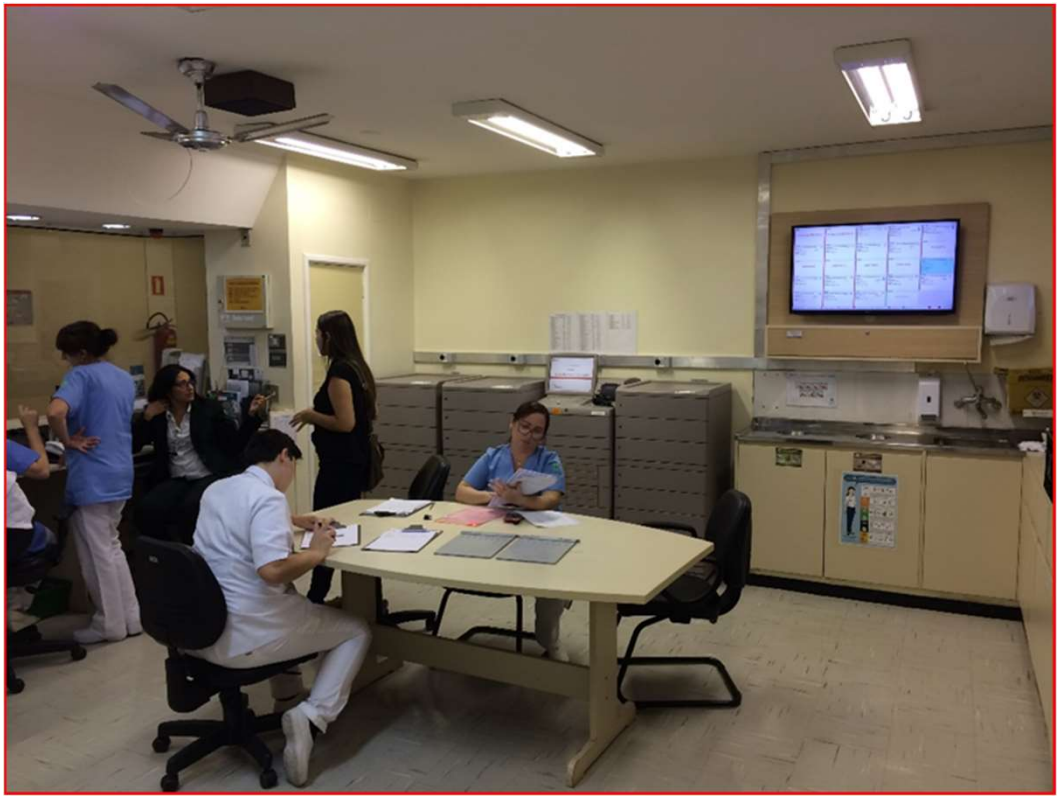
Análisis de la preparación y administración de medicamentos en el contexto hospitalario con base en el pensamiento Lean



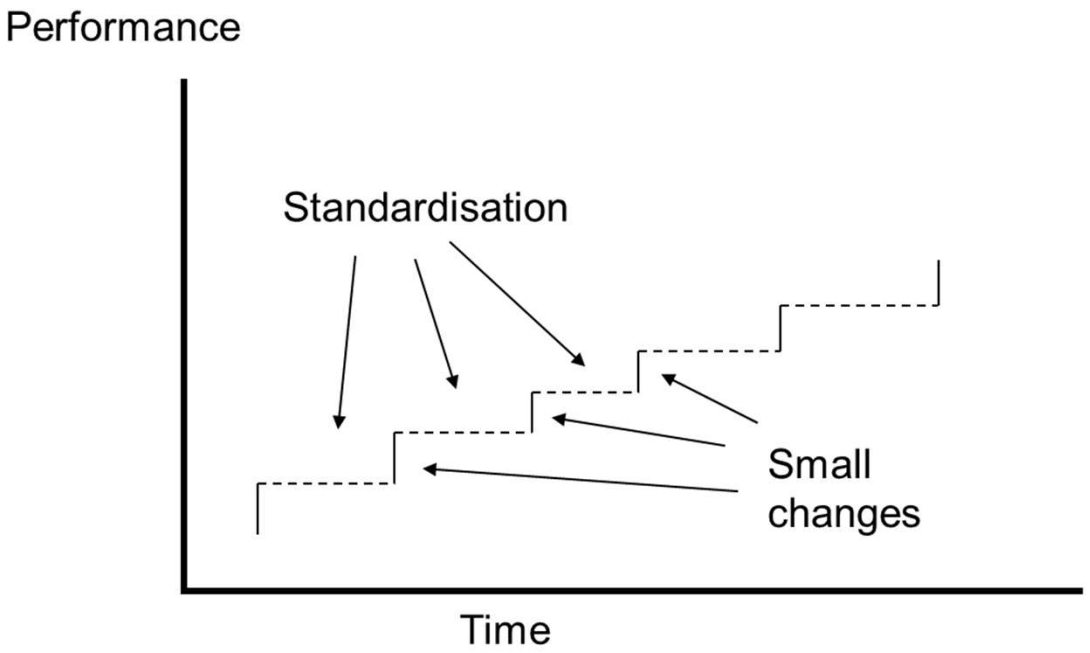
Not all improvements were synergistic

Repositioning of supplies in the cabinet reduced akward postures and workload

Patient dashboard increased workload



What do interactions between kaizen projects look like?



PRODUCTION PLANNING & CONTROL
2019, VOL. 30, NO. 16, 1337–1353
https://doi.org/10.1080/09537287.2019.1615649

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A complexity theory perspective of kaizen: a study in healthcare

Dayane Maximiano Carvalho Ferreira and Tarcisio Abreu Saurin

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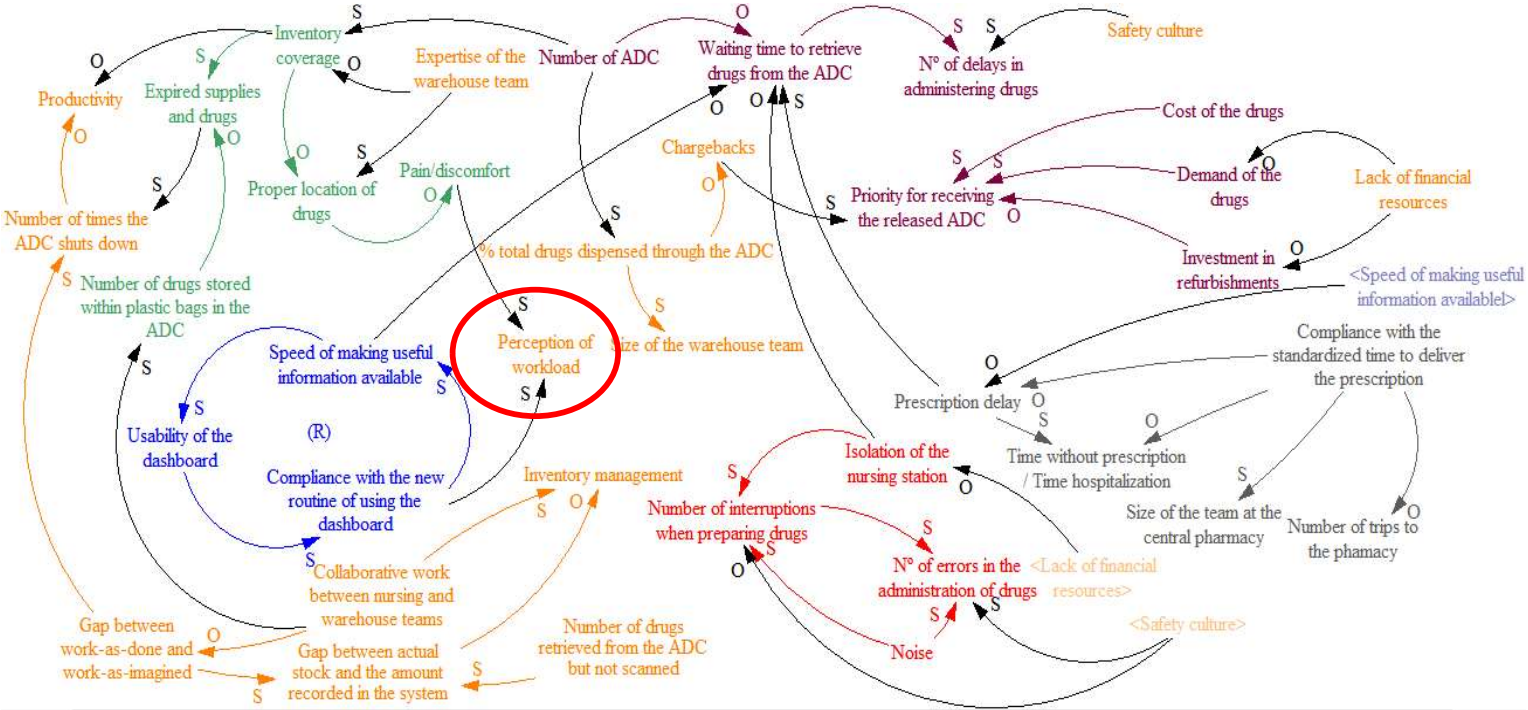
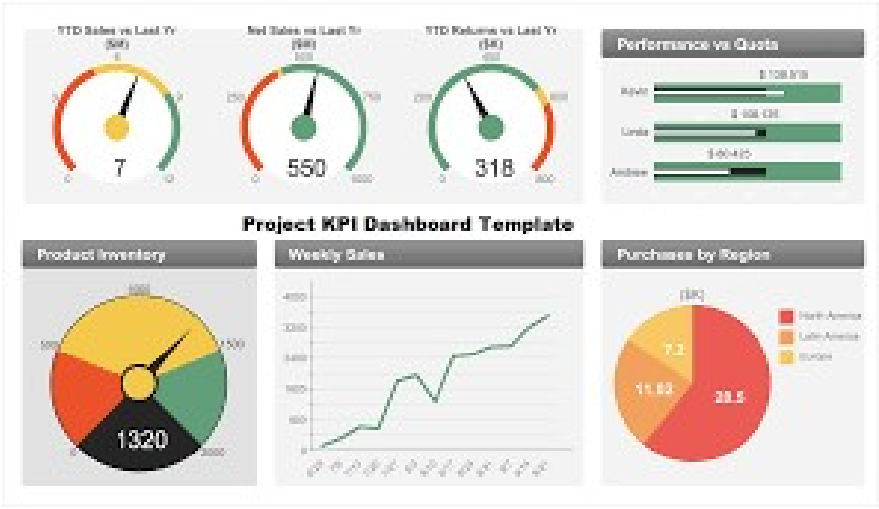


7

Giving visibility to performance variations

Examples of visual management

Real time inspection of dehydration when peeing



Oil leak is easily detected if the equipment is clean

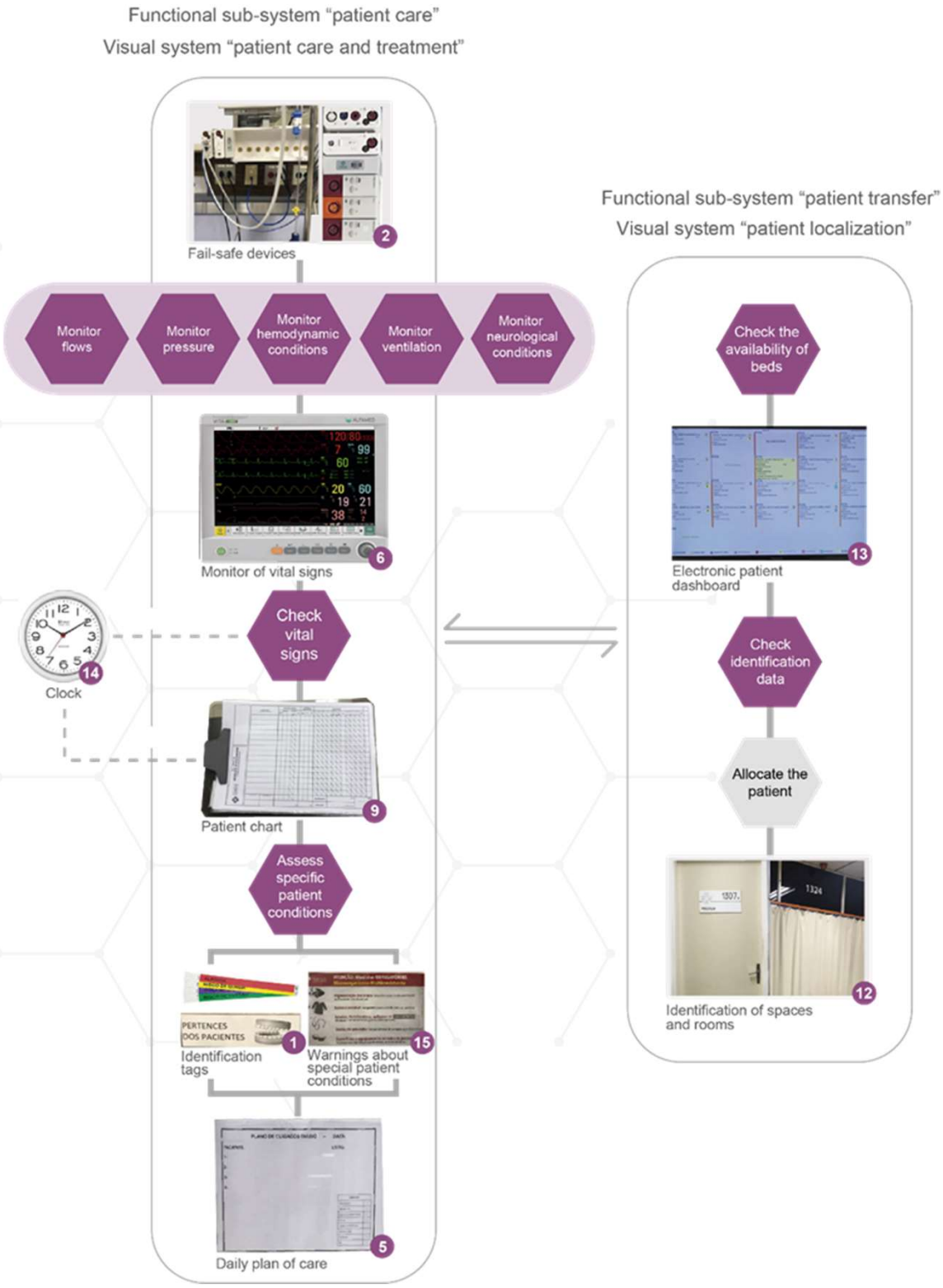
Understanding how visual devices interact with each other in an ICU

PRODUCTION PLANNING & CONTROL
https://doi.org/10.1080/09537287.2023.2225457

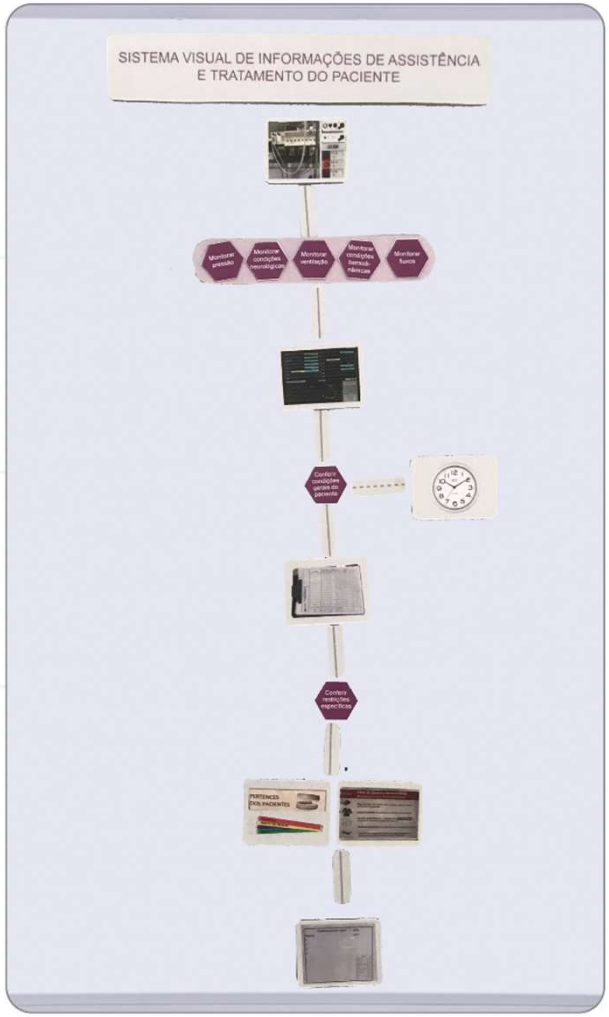
A framework for the analysis of emergent visual systems

Carolina Melecardi Zani and Tarcisio Abreu Saurin

FRAM allows the identification of emergent visual systems



Game with magnets to connect visual devices to functions that use them, identifying hidden visual systems



Resilience Assessment Grid (RAG) – Systemic Potentials Management (SPM)

Appendix A. Resilience Assessment Grid (RAG) questionnaire. Notes: (i) questions referred to as "original" are those from the original RAG by Hollnagel (2011); (ii) questions referred to as "adapted" correspond to those from the original RAG by Hollnagel (2011), which were reworded as to facilitate their understanding in the construction context

	Functions of the SPMS	Questions	Sources
Respond	1. Use of indicators in safety and production planning meetings	1.1 Do results of safety indicators support decision-making in safety and production planning meetings? 1.2 Which safety indicators are used in these meetings? 1.3 How often are the indicators used in safety planning? 1.4 How often are the indicators used in production planning?	Hinze et al. (2013)
	2. Collaboration with front-line workers, supervisors, managers, and other departments (design, production, quality, etc.)	2.1 How are project participants involved in safety activities, such as job hazard analysis, planning meetings, and inspections?	Hallowell and Gambatese (2009)
		2.2 Who has the authority to stop work, without waiting for approval from site management?	Saurin et al. (2008)
		2.3 How is the stop work authority put into practice?	
	3. Managing the trade-off between safety and productivity	3.1 How are conflicts between safety and productivity managed?	Adapted from original *(Is there a trade-off between, e.g., safety and productivity?)*
		3.2 In which construction phases are these conflicts more likely to occur?	
	4. Improving training	4.1 Are the results from safety indicators used to improve training? How?	Hinze et al. (2013)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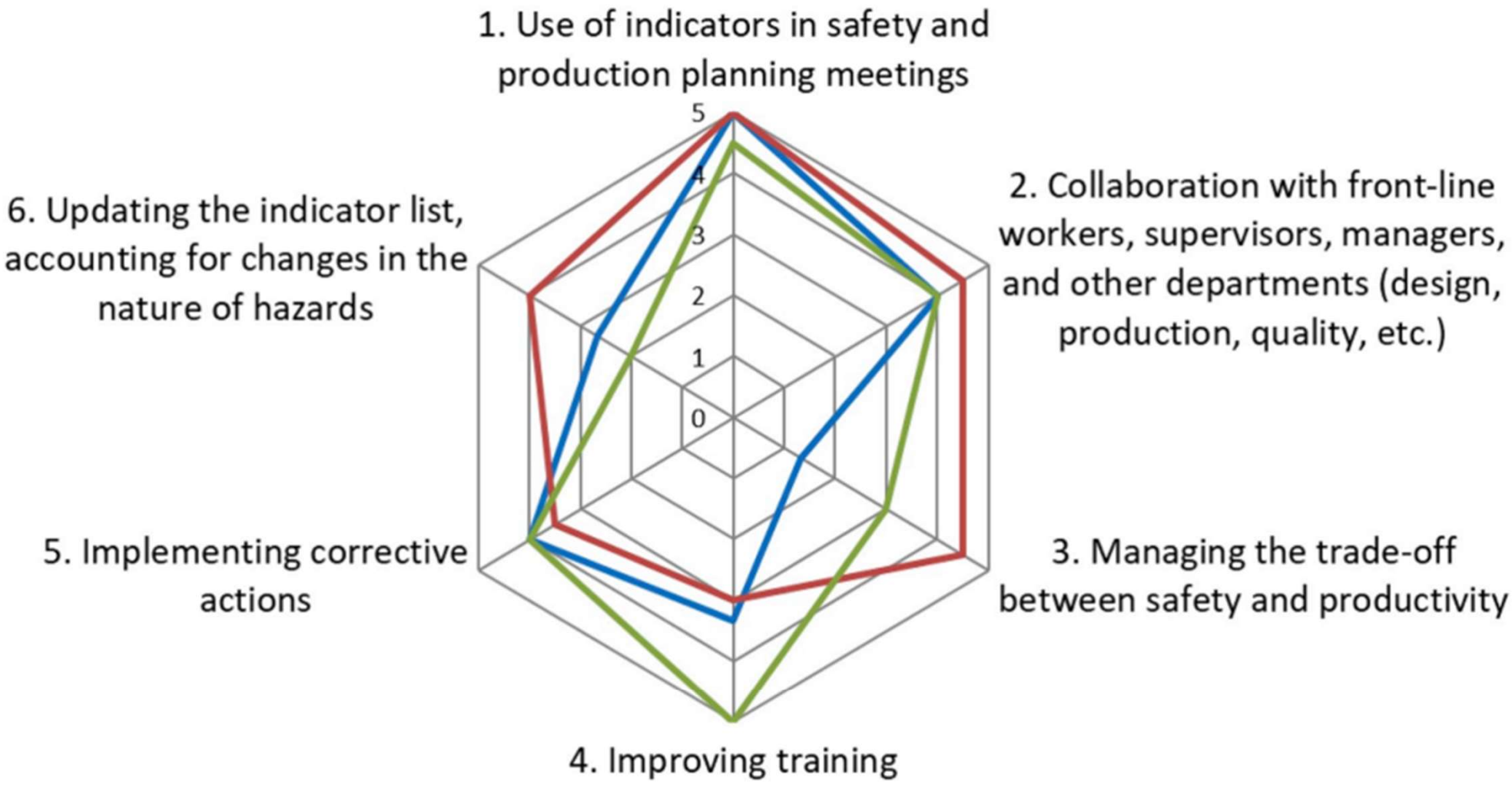
Monitoring complexity and resilience in construction projects: The contribution of safety performance measurement systems

Guillermina Andrea Peñaloza [a,*], Tarcisio Abreu Saurin [b], Carlos Torres Formoso [c]

Presenting results of RAG



What else makes a good design for RP?

- ✓ *Consistent designs across* the micro, meso, and macro levels
  - ✓ E.g., regulations (macro level) demanding the use of certain slack resources

- ✓ *Information from direct sources*, *time lag as low as possible* between information gathering and decision-making
  - ✓ Pre-task safety planning on the site where activities will occur

- ✓ *Customized designs* that meet preferences of designers
  - ✓ Note-taking during tool box safety meetings

Joint 11th Biennial Symposium of the Resilience Engineering Association and 14th Annual Resilient Health Care Society Meeting

Resilient Health Care Society

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Collaboration Across Boundaries for Adaptation in the Era fo Complexity

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Gracias!

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