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Building a functional resonance analysis method (FRAM) in healthcare: a systematic review on how steps are reported, defined and supported by data

Nienke Maria Luijcks [1], Tom Bazuin [2], Arie Adriaensen,[3] Annelies Visser [4], Dave Dongelmans,[5] Jop Groeneweg,[1] Maarten J van der Laan [2], Perla Marang-van de Mheen [6]

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For numbered affiliations see end of article.

Correspondence to
Nienke Maria Luijcks;
n.m.luijcks@tudelft.nl

ABSTRACT

Objectives The functional resonance analysis method (FRAM) is increasingly used to analyse healthcare processes. FRAM uses four steps to analyse a process and its potential variability. We systematically reviewed studies using FRAM in healthcare on how the four steps in FRAM are reported, defined and supported by data.

Design Systematic review following the preferred reporting items for systematic reviews and meta-analyses 2020 guidelines.

Data sources Web of Science, PubMed, Embase, Scopus, PsycINFO, Dimensions and Lens were searched up to December 2025.

Eligibility criteria for selecting studies All peer-reviewed studies using FRAM in a healthcare context that presented a FRAM visualisation were included. The papers had to be written in English.

Data extraction and synthesis Two independent reviewers screened titles and abstracts, and subsequently the full text of selected papers. Data was extracted reporting on the steps of FRAM, how functions were supported by data, and the functions and couplings of the visualisations.

Results Sixty-eight papers were included, of which 20 (29%) reported at least one aspect of all four steps in FRAM. While most studies (85%) described how functions were supported by data, the methods used varied widely. Terminology was interpreted differently concerning variability, the output of variability and the effect of combined variability.

Conclusion Most FRAM studies in healthcare do not report all steps of FRAM, and interpretations of key terms differ. FRAM studies should more clearly describe which steps of the method are conducted, and how data is collected and analysed. Refinement of FRAM guidelines, particularly on data use and terminology, would enhance consistency and comparability across studies.

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STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This study used a predefined data extraction tool that operationalised functional resonance analysis method (FRAM) steps, terminology and data use, thus improving reproducibility and transparency.
- ⇒ The assessment of couplings in FRAM visualisations in this review can be prone to error, as these were counted and validated manually. For visualisations with many crossing lines, it was difficult to distinguish different couplings which might have induced errors.
- ⇒ A limitation is that the quality of each study or FRAM analysis was not assessed, as unlike systematic reviews of randomised controlled trials or observational studies, there is no valid tool available to conduct these assessments.

INTRODUCTION

The functional resonance analysis method (FRAM) is increasingly used in healthcare[1 2] given its ability to capture real-world clinical work by showing how various activities (called functions) interact in complex processes.[3] The analysis focuses on the dynamics between functions rather than individual factors, which is relevant for socio-technical systems such as healthcare.[2] The method is particularly useful for analysing the distribution of roles and responsibilities in workflows, for example,[4–6] which increases the understanding of the process by incorporating multiple stakeholder perspectives. Specifically, FRAM consists of four consecutive steps that analyse how a system works, including how steps interact and affect the process.[7] However, it is currently unclear how studies in healthcare perform these steps in practice.

According to the FRAM guidelines described by Hollnagel,[7] FRAM starts with step 0 which specifies the scope, that is, choosing the working process and identifying stakeholders. In step 1, functions within the process and how they are connected are identified (through couplings) and the FRAM visualisation is created. Step 2 describes the potential variability of these functions: what function (outputs) may vary and how they vary. Step 3 describes the aggregation of variability, that is, how the variability of different functions could influence overall system outputs. Finally, step 4 presents the consequences of the analysis, which describes how uncontrolled variability could be managed.

Previous reviews on FRAM in healthcare include a scoping and a systematic literature review.[8 9] Although these reviews differed in how they reviewed the aims, scope and purpose of studies, both mention the data sources used in FRAM (eg, interviews). However, neither review provided insight into how the individual FRAM steps were defined or grounded in empirical data. It is important that studies report how the FRAM visualisations represent the data used, particularly whether functions within the FRAM reflect the view of one or multiple stakeholders. A guideline based on common practice using FRAM was published, but only discussed the first two steps.[10] Another review included FRAM studies across various domains, including healthcare, which described the percentages of steps reported[1] but did not provide qualitative insights into how these steps were defined or analysed. To gain deeper insights, a more qualitative exploration is required that goes beyond quantitative counting of FRAM steps.

Therefore, this study aims to assess how FRAM studies in healthcare report: (1) The number of steps reported, (2) The definition of each step and (3) How each step is supported by empirical data.

METHODS

Our study aims to confirm current practice and define possible variation in FRAM steps, for which a systematic review is appropriate.[11] The methodology of this review follows the preferred reporting items for systematic reviews and meta-analyses 2020 guidelines.[12] A protocol was published in PROSPERO before starting this review.[13]

Search strategy

The following databases were searched: Web of Science, PubMed, Embase, Scopus, PsycINFO, Dimensions and Lens. The search strategy consisted of: ("Functional Resonance Analysis Method" OR FRAM) AND (healthcare OR hospital* OR clinic* OR "healthcare" OR "health service*" OR medical OR "health system*" OR nursing) and was adjusted accordingly per database. The search strategy (online supplemental appendix A) was applied in October 2024, updated in December 2025 and all titles and abstracts were extracted.

Criteria for inclusion

Studies were included if they applied FRAM in a healthcare context and presented FRAM visualisations. Multiple FRAM visualisations in a study were also included. We only included peer-reviewed journal articles written in English. Scoping, systematic and meta-reviews were excluded, but the reference lists were screened for eligible studies.

Within the included sample of papers, only FRAM visualisations that clearly showed how the lines connected to the couplings were analysed. If it was not possible to see how couplings are linked (ie, when lines significantly overlap), accurate interpretation is impossible. All remaining information within the paper, such as the described steps, was still analysed.

Screening of studies

The identified citations from the search strategy were imported into RAYYAN[14] and duplicates were removed. Two reviewers (NML, TB) independently screened titles and abstracts for eligibility based on the predefined criteria. Full-text papers of included studies were retrieved and independently reviewed by the same reviewers. If necessary, authors of the included studies were contacted, for example, when FRAM visualisations were not shown. The reasons for exclusion of full-text papers were reported. In each stage, differences between the reviewers were resolved through discussion or an independent expert (AA) if needed.

Data extraction

Two reviewers (NML, TB) independently extracted data from the selected full-text papers using a predefined extraction tool (online supplemental appendix B). The data extraction tool was piloted on three papers (NML) and refined in consultation with a FRAM expert (AA). Article information such as title, authors and year of publication was extracted. In addition, we extracted text from the papers describing the steps taken within the FRAM analysis and the evidence provided for each step, similar to extracting the codes and/or themes in reviews of qualitative studies. For each step, we specified several aspects as described in the handbook of FRAM:[7]

- Step 0: aim, setting, reason for choosing work process, reason for choosing FRAM.
- Step 1: Work-as-Imagined versus Work-as-Done or only Work-as-Done, evidence source(s), how functions were derived from data, FRAM visualisations.
  - FRAM visualisations: number of functions, active couplings (eg, using the Control coupling), type of functions (social, technical or organisational).
- Step 2: describing the variability of the output of a function in FRAM, how variability affects other functions, for example, time or delay.
- Step 3: how combined variability could lead to unexpected outcomes, description of upstream and downstream couplings.
- Step 4: consequences of the analysis.

A step was considered reported if the study addressed at least one of the predefined aspects for that step.

Data analysis and presentation

We focused on how the steps within FRAM were reported rather than providing a judgement on the quality of a study, although good quality reporting is an important prerequisite and therefore could be considered a proxy

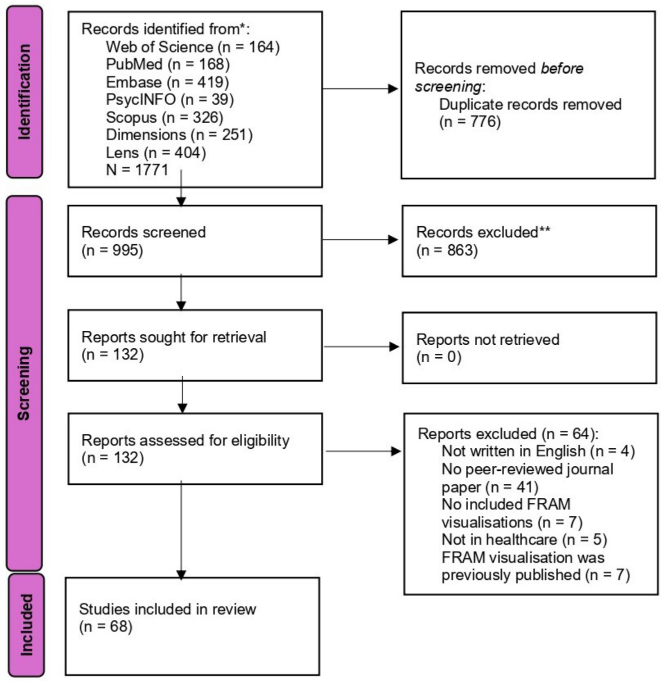

Figure 1 Preferred reporting items for systematic reviews and meta-analyses chart. Search results, screening and included papers. FRAM, Functional resonance analysis method.

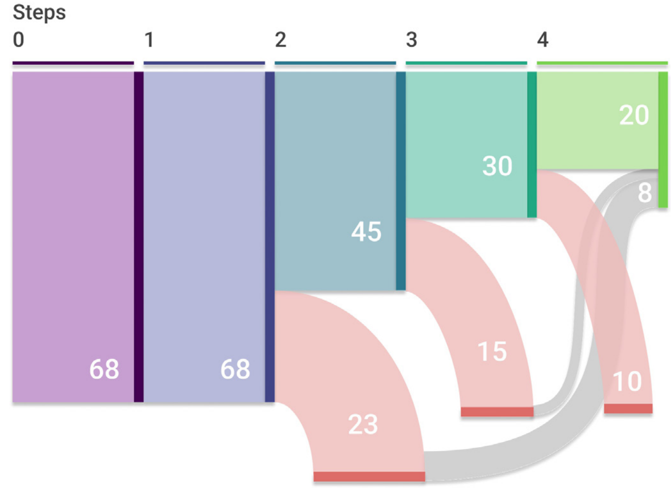

Figure 2 Sankey diagram of all functional resonance analysis method steps. Step 0: setting the scope. Step 1: describe the functions. Step 2: describe potential variability. Step 3: aggregation of variability. Step 4: consequences of the analysis.

for quality. We analysed the extracted text from all studies for each step to assess how these steps were interpreted and reported. An overview of which studies completed the four steps of Hollnagel was visualised in a Sankey diagram. In addition, the extracted results were tabulated. Specific quotes extracted from the studies were analysed through thematic analysis using Atlas.ti (V.25[15]). Thematic analysis focused on sub-elements of multiple steps of FRAM: step (1) how functions were supported by data, in step (2) the interpretation of terminology and the output of variability in that function, in step (3) how combined variability was described. Descriptive statistics were used to summarise quantitative information from FRAM visualisations, using means and SD, which another researcher validated in different software (JG).

Patient and public involvement

Patients and the public were not involved in this study.

RESULTS

Source inclusion

The database search identified 1771 papers (figure 1). After removing duplicates, 995 papers were screened on title and abstract, of which 863 were excluded. The full text of 132 papers was retrieved. Authors of 6 papers were contacted to retrieve the full FRAM visualisations of the studies; 1 provided the requested material. Checking the references from systematic literature reviews, scoping reviews and best practice articles[1 2 9 10 16–19] did not result in additional studies. A total of 68 papers were included.

Reporting steps of FRAM

All 68 studies described at least one aspect of step 0 (setting the scope) and step 1 (describing the functions), as shown in the Sankey diagram in figure 2. At least one aspect of step 2 (defining potential variability) was described by 45 studies, 23 studies did not mention any aspect of this step.[20–42] Of these 45, 30 studies described aspects of step 3 (the aggregation of variability), and the remaining 15 did not mention any aspect of step 3.[43–57] Of these 30 studies, 20 described aspects of step 4 (consequences of the analysis); thus, these studies described all steps of FRAM,[54 58–76] and 10 studies did not.[6 77–85] There were six studies describing step 0, 1 and step 4,[32–34 36 42 56] and two studies did not mention any aspect of step 3 but at least one aspect of step 4.[21 32–34 57] In total, 28 studies described step 4.[21 32–34 36 54 57–76] For a full overview of all steps and sub-steps, see online supplemental appendix C.

Step 0: defining the scope

Most studies (n=66, 97%) defined the aim, 21 studies (31%) described multiple aims. The goal was mostly to understand either the process, variability or everyday practice (n=39, 57%). Other aims included process improvement (n=23, 34%), comparing Work-as-Imagined and Work-as-Done (n=10, 15%), applying a new version of FRAM or combining it with other models (n=6, 9%) and to identify risks, barriers and facilitators (n=7, 10%). Most studies were set in hospitals (n=51, 75%), followed by primary care (n=11), regional/transitional care (n=4), home care (n=2) and prehospital care (n=1). Four studies used a simulation or artificial intelligence, rather than a physical setting.

A majority described a reason for the selected working process (n=57, 84%). The complexity of the process (n=14), patient risk (n=13), the need for insight in Work-as-Done (n=12), quality improvement (n=5) and a current inefficient process (n=5) were mentioned most often. Furthermore, 45 studies (66%) provided reasons for choosing FRAM as a method, mostly mentioning the need for using a systems approach (n=11), modelling Work-as-Done (n=9) and understanding the complexity of a process (n=7). A full overview of reasons to select the working processes and FRAM can be found in online supplemental appendix D.

Step 1: describing the functions

In 26 studies (38 %), both Work-as-Imagined and Work-as-Done were analysed, the remaining studies (62%) only investigated Work-as-Done. In 50 studies (73%), more than one evidence source was used for data collection. On average, 2.28 different types of evidence sources were used (SD=1.06). Interviews were used most (n=55, 81%), followed by document analysis (n=34, 50%), observations (n=29, 43%) and focus groups or workshops (n=15, 22%). Other sources were surveys, questionnaires, simulations and prompts, literature studies, routine monitoring data, interpretative phenomenological analysis, experience of the research team, key process timings and feedback sessions. In two studies, it was unclear what evidence sources were used.[26 28] Two studies used a supporting task or activity for the FRAM visualisation: a hierarchical task analysis[22] and an analysis concerning “functional purpose, generalised function and physical functions”.[61]

In 58 studies (85%), the process of deriving functions from data was described, although the methods used varied widely. Ten different analysis techniques were described, of which an iterative analysis process (n=12) was mentioned most often. A total of 11 studies either described content or thematic analysis. Some studies described more detailed steps within the analyses, such as coding (n=20) and dividing the data into themes (n=19). Additionally, studies differed in what they aimed to identify. Most studies (n=37) aimed to identify functions, others described identifying connections and interactions between functions (n=20). The identification of potential variability was mentioned in ten studies. Finally, multiple studies described aspects related to the reliability of the methodology: 18 studies reported independent analysis by at least two authors, 14 studies described reaching consensus among authors and one study mentioned inter-coder reliability assessment. The functions were described in 65 studies, either in text (47, 69%) or in tables (21, 31%). Of these textual and tabulated results, 13 studies (19%) used quotes from their sources to support the description of functions.

FRAM visualisations

In 68 studies, a total of 113 FRAM visualisations were shown. After excluding the visualisations in which couplings could not accurately be assessed, 104 visualisations remained for analysis (table 1). See online supplemental appendix E for the number of functions and couplings per study.

Table 1 Summary of functional resonance analysis method visualisation findings

Function type	Couplings	Mean	SD
Foreground functions		14.38	7.88
	Input	12.76	8.23
	Control	3.50	4.09
	Time	1.35	1.94
	Precondition	4.54	4.75
	Resource	3.86	4.44
	Output	14.34	9.69
Background functions		8.33	10.25
	Input	1.34	1.34
	Control	1.57	2.71
	Time	0.83	2.69
	Precondition	1.21	2.62
	Resource	1.51	2.44
	Output	1.85	3.35
All functions combined		22.70	14.68
Function context		**N of visualisations**	**%**
	Social	104	100
	Technological	25	32
	Organisational	12	15

All 104 visualisations used foreground functions (100%) and 68 used background functions (65%). On average, the FRAM visualisations contained 22.7 functions, with large variation between visualisations (SD=14.7). Input and Output couplings were the most common in foreground functions. The coupling time was used the least in both foreground (M=1.3, SD=1.9) and background functions (M=0.8, SD=2.7) compared with other couplings. Looking at the type of functions, all visualisations used social functions, 25 (32%) visualisations used technological functions and 12 (15%) used organisational functions.

Most studies (n=48, 70%) extended the FRAM visualisations, particularly using colours to define either roles or groups for the hexagons (n=48). Others added legends (n=11), timelines or other forms of linearity (n=5) and steps to define groups of functions (n=5).

Validation of the FRAM visualisations involving stakeholders was mentioned in 40 studies (59%), mostly through workshops or meetings (n=28 studies). Other methods of validation concerned checking, interviews, surveys, audits, scenarios, independent coding, comparison to expectations of the Work-as-Done or ‘testing’. In 57 studies, specific stakeholders involved in the FRAM visualisations or the validations were described: healthcare professionals (n=34), the research team (n=9), risk and safety managers (n=3), management (not further specified; n=3), FRAM experts (n=3), improvement scientists (n=1), policy makers (n=1), consultants (n=1), administrative staff (n=1) and architects (n=1).

Step 2: describing the potential variability

There was large variation in how the 45 studies reported the sub-elements of step 2 describing potential variability. In 39 studies, the variability of the output of the functions or the functional couplings was mentioned. For example, "Variability was mainly identifiable in the function: <To assess the situation on the ward> as this assessment is conducted depending on the opinion of a nurse involved in injectable medication administration".[66] However, the definition and interpretation of variability differed across the studies. Variability was mostly defined within a function that affected other functions (n=13). Variability within a function without mentioning its effects was described in 10 studies. Four studies defined varying actions of stakeholders as variability. Twelve studies used various other definitions of variability, resulting in eight additional interpretations.

Variability of output functions was described in 31 studies. For example, "Several nurses raised the issue with the unreachability of the parents, as reaching the parents from the given contact numbers can be difficult. The variability in a single activity is likely to aggregate and, in turn, *delay* other activities (eg, checking and distributing drugs)".[60] How variability of output functions was defined and described differed between studies. Most studies described the effect of variability on other functions (n=16), or the different types of outputs of a function (n=7).

Step 3: the aggregation of variability

In 21 of the 30 studies describing at least one aspect of step 3, it was mentioned how combined variability of different function outputs could lead to unexpected outcomes or positive resonance. Mostly, this was done by describing the influence of a function on outcomes (n=17). For instance, "This has the consequence of increasing the patient's estimated date of discharge as the therapeutic plan will be modified when accurate information is made available".[65] Two studies described the reason for unexpected outputs, of which one study described the history of the variability and how this affected the outcome. Another discussed how a function was managed by the variability of other functions.

The effect of upstream-downstream functions in the process was described in 13 studies. For example, "Prior to this function lies the upstream functions "make sense on territory conditions" and "decide routes", acting as the link between visit planning and visit execution. These are pivotal functions in a way that they are bottlenecks, enabling all downstream patient visit activities".[71]

Step 4: consequences of the analysis and additional steps

In 28 studies (41 %), the consequences of the FRAM analysis were reported. For instance, "[…] Our suggestion is to align the user's smart bracelet with the healthcare app through NFC and report the user's location and heart rate information in real time as an aid to the user's hypoglycaemia detection".[63] Most descriptions focused on the suggested improvements of the investigated process (n=27), or describing the effect of scenarios (n=1). Further steps or extension of the FRAM analysis, such as Monte Carlo simulations or ergonomic work analysis, were mentioned in 25 studies.

DISCUSSION

Statement of principal findings

This research demonstrated that most studies using FRAM in healthcare do not report all steps, with only 20 studies (29%) reporting at least one aspect of all four steps. In addition, large variation was found in how each step was reported. In step 1, most studies described how the data were used to identify the functions, though they employed a wide variety of methods. The number of functions and the frequency of couplings in FRAM visualisations also differed, potentially reflecting the different working processes analysed. Studies also differed in how they described and interpreted steps 2 and 3, particularly in their definitions of variability and its outcomes.

In the FRAM handbook, Hollnagel describes three reasons for output variability in a function: internal variability due to the function's nature, external variability due to the environment and influences of (earlier) upstream functions.[7] The definitions found in the analysed studies partly fit these reasons. Specifically, studies described 'variability within a function' which can be interpreted as internal variability, and 'the variability of a function affecting another function' can be defined as influences propagated from upstream functions. However, multiple studies did not define variability as described in the handbook, for example variation between data and Work-as-Done or the varying actions of stakeholders. Since variability is a key component of FRAM, a shared understanding and definition of variability is needed. The variation in definitions and interpretations makes it difficult to compare the results from FRAM studies.

Strengths and limitations

A strength is that the qualitative analysis provides further insights into how the steps of FRAM are reported and highlights how researchers interpret the guidelines differently in practice. Although the increased usage of FRAM has been well documented,[1 9] this is the first study to systematically examine how its steps are described. It is also the first to systematically analyse how FRAM visualisations are conducted, and how some couplings are used in practice.

A limitation is that the quality of each study or FRAM analysis was not assessed, as unlike systematic reviews of randomised controlled trials or observational studies, there is no valid tool available to conduct these assessments. Still, good quality reporting, thus describing the steps taken in FRAM analysis, is essential, and in that sense, can be taken as a proxy. Another limitation is that assessing the couplings in FRAM visualisations can be prone to error, as the couplings were counted and validated manually. For visualisations with many crossing lines, it was sometimes difficult to distinguish different couplings. One promising tool to quantitatively analyse and evaluate the characteristics of FRAM models, which is currently being developed, is the FRAMalyse by Grabbe and Du.[86] This could further improve quantitative analysis of FRAM models, which should go hand in hand with qualitative judgement. The ability to distinguish the relationships of functions could be another indicator of quality, since the visualisation should help both stakeholders understand the selected process and the scientific community interpret the results.

Interpretation in the context of the wider literature

Previous reviews of FRAM studies showed that multiple data collection methods were used, such as workshops.[1 2 9] Our results add that multiple data analysis methods are applied to identify functions from collected data. The decisions for using one method over the other should be described, to ensure that the methods and rationale are clear and transparent.[10] In an earlier systematic review, 81% of the 16 FRAM studies in healthcare validated their visualisations,[2] which is higher than the 59% found in our study. This difference could be explained by the larger sample size of our study, or that the use of validation has decreased over the past years. The guidelines of FRAM should therefore more explicitly include validating the visualisations.

There are differences in how studies implement the FRAM, making it difficult to compare results or draw consistent conclusions. A previous systematic review reported a higher number of studies following the later steps of FRAM, especially steps 3 and 4. This could possibly be explained by domain differences. Studies in healthcare focus less on the later steps of FRAM compared with other domains, possibly since in healthcare many FRAM studies focus on understanding a process, rather than on variability. Lack of time could play a role regarding the number of steps performed. Another possibility could be that FRAM studies are mostly conducted by healthcare staff who are less knowledgeable regarding resilience and variability. This has not been systematically investigated for FRAM specifically, but seems likely given that other methods such as the root cause analysis are known to be mostly conducted by healthcare staff rather than accident investigators.[87]

This focus on earlier steps raises the question of whether all steps of FRAM should necessarily be performed in each study, or if this should depend on the aim. For instance, multiple studies described their aim to be 'understanding a working process' for which following step 0 and step 1 is likely sufficient to answer their research question. Alternatively, if the aim is to define and analyse variability in a process which often also involves quantification, the later steps become relevant. This could also explain the studies that did not describe aspects of steps 2 and 3, but still described the consequences in step 4. If a specific number of FRAM steps are used, it is important to specify which steps are performed in the study. Adding the reported steps can contribute to the generalisation of FRAM studies since the difference between the steps followed is better highlighted.

It has been proposed not to exceed 20 functions in healthcare FRAM visualisations, thereby keeping a thorough overview of a process.[88] However, there is no evidence on the frequency of functions supporting this proposal. We found that on average 22.7 functions were used per FRAM visualisation, thereby providing approximate support for the previous proposition, but with large variation between studies given the SD of 14.7. This variation could be explained by differences in decisions of the researcher regarding the scope, the nature and the amount of detail needed to analyse a process. These decisions should be reported thoroughly in FRAM research. Second, we found that the function coupling Time was used least, even though multiple studies not using this coupling concluded that time played a large role in the researched processes.[23 25 50 55 58 60 63] These studies mentioned factors such as a high workload and time pressure, administering medication or timely replacement of medical instruments as important. Limited use of the Time coupling was also found in a review of studies using FRAM and other resilience engineering analyses[89] which indicates that this goes beyond healthcare studies. Although the factor time is discussed in steps 2 and 3 of FRAM, it makes sense to also assign time a significant role in the functions (step 1) when concluding that time is important. It is notable that the terminology for the time coupling is broad and can be interpreted as duration, a functional condition, or as progressing time. According to recent descriptions on how to use FRAM, the Time coupling can also be used as a Resource or Precondition coupling.[90] Whether the Time coupling has added value or can be removed given that it creates confusion could be further investigated and discussed.

Implications for policy, practice and research

The abovementioned findings on how steps are described and how variability is interpreted have practical implications for the FRAM guidelines. A recommendation to future FRAM studies would be to use the term variability only as specifically intended by FRAM, as referring to different forms of performance variability. It is preferable that all studies follow the same steps and terminology. On the other hand, it could be valuable for FRAM studies to choose methods that best suit their aim, as long as these decisions are made explicit. For instance, the use of data sources to collect data, what analysis is used to derive functions from data, or showing how the functions are supported among stakeholders. The data extraction tool used in this study (online supplemental appendix B) could serve as a checklist for future researchers to specify their use of data and the contents of FRAM steps. In addition, this checklist could serve for training and educational purposes to ensure that researchers conducting FRAM studies understand the essential elements of each step and the importance of underpinning them with empirical data. Currently, the ways in which data is handled are underexposed in both the original handbook[7] and current guidelines[90] on using FRAM and require more attention and guidance.

Conclusions

In the healthcare context, studies do not report all steps of FRAM and use different definitions and interpretations of the terminology. This significantly impacts how variability is interpreted, its effect on outcomes and what is included in FRAM visualisations. Complete reporting of the number of steps or why some were not needed given the study aim, how steps are performed and supported by data supports transparency and research on consistent application of FRAM methodology. This calls for the development of standardised protocols or frameworks for applying the FRAM in healthcare to ensure the clarity of the steps and how to perform them. Our findings offer concrete suggestions for improving FRAM guidelines, particularly regarding clarity on step execution and reporting. Strengthening these aspects will help healthcare organisations use FRAM more effectively to improve their processes and, in turn, enhance the quality and safety of care.

Author affiliations
[1]Department of Safety and Security Science, Centre for Patient Safety, Delft University of Technology, Delft, the Netherlands
[2]Department of Surgery, University Medical Centre Groningen, Groningen, the Netherlands
[3]Department of Multi Actor Systems, Delft University of Technology, Delft, the Netherlands
[4]Department of Surgery, Amsterdam UMC Location AMC, Amsterdam, the Netherlands
[5]Department of Intensive Care Medicine, Amsterdam University Medical Centre, Amsterdam, the Netherlands
[6]Safety and Security Science, Delft University of Technology Faculty of Technology Policy and Management, Delft, the Netherlands

Contributors Conceptualisation, NML, TB, DD, JG, MJL and PMM; methodology, NML, TB, AA, DD, JG, MJL and PMM; software, NML and TB; validation, NML, TB, AA and JG; formal analysis, NML and TB; investigation, NML and TB; data curation, NML and TB; writing—original draft preparation, NML; writing—review and editing, NML, TB, AA, AV, DD, JG, MJL and PMM; visualisation, NML; supervision, PMM, JG and MJL; project administration, NML and TB. All authors have read and agreed to the published version of the manuscript. Guarantor: NML.

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ORCID iDs
Nienke Maria Luijcks https://orcid.org/0009-0005-2404-4811
Tom Bazuin https://orcid.org/0009-0001-9134-9704
Annelies Visser https://orcid.org/0000-0001-7102-2627
Maarten J van der Laan https://orcid.org/0000-0002-3125-1342
Perla Marang-van de Mheen https://orcid.org/0000-0003-1439-0989

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