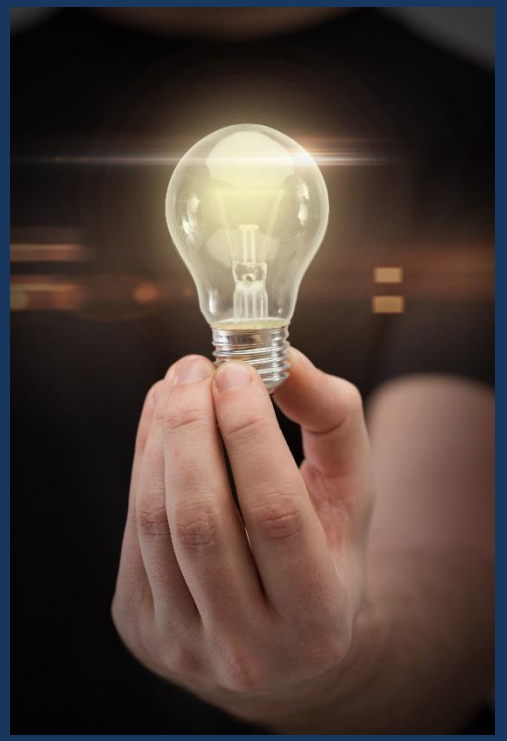
10th International Conference
MANAGING FATIGUE

Accepting Complexity and Maintaining Coherence:

Results of a Research Project to Develop a Visual Representation Approach for the Field of Fatigue Management



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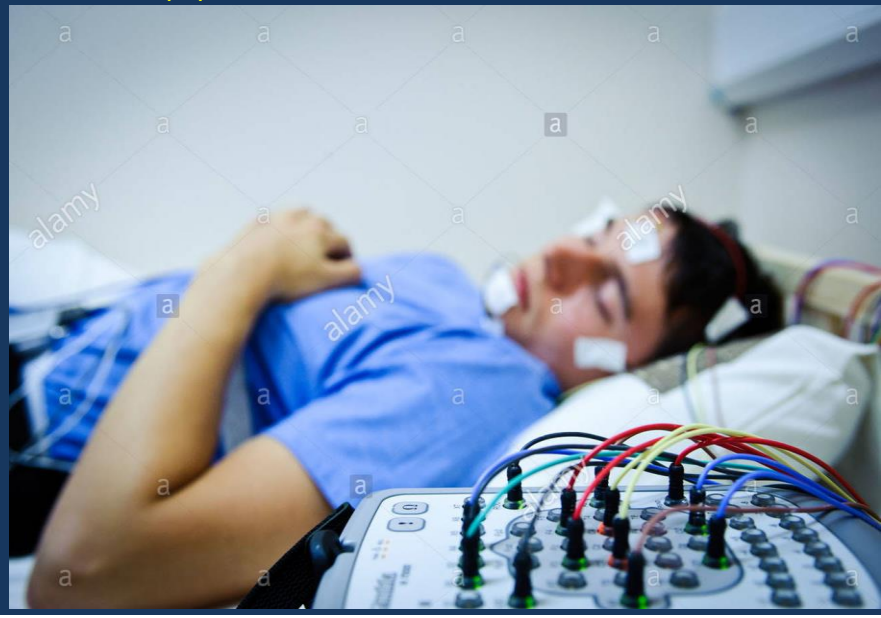
Background

- In the Fatigue Management community we continue to learn a great deal from studying individual fatigue-related variables in highly controlled environments.
- For example, in Rupp, *et. al.* (2009) increased one group's nightly sleep opportunity in the laboratory to 10h TIB while another group were given ~7h TIB, for a week prior to a 13d sequence of baseline, sleep restriction and recovery.
- They demonstrated the week of prior sleep extension improved objective performance during and after restricted sleep.

www.alamy.com/stock-photo-sleep-lab-eeg-monitoring-machine-equipment-electrodes-and-wires-with-38098328.html



Rupp TL; Wesensten NJ; Bliese PD; Balkin TJ. Banking sleep: realization of benefits during subsequent sleep restriction and recovery. SLEEP 2009;32(3):311–321. Open access version: www.ncbi.nlm.nih.gov/pmc/articles/PMC2647785/

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Controlled Studies

- In workplace research, we also continue to learn a lot from observing fatigue-related variables in controlled ways, with and without specific interventions.
- For example, in Sallinen, *et. al.* (2017) three groups of pilots had their objective sleep, self-reported (subjective) alertness and other measures recorded in all phases of short-haul and long-haul flights for approximately two months.
- Amongst other findings, the team demonstrated the critical operational risk exposure impacts of night flying, and made clear conclusions about the context in which their results should be generalized.

Sallinen M, Sihvola M, Puttonen S, Ketola K, Tuori A, Härmä M, Kecklund G, Åkerstedt, T. Sleep, alertness and alertness management among commercial airline pilots on short-haul and long-haul flights. Accident Analysis & Prevention 2017; 98:320-329.

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Dynamic Contexts

- The best approach to investigating a specific research question will always depend on a range of factors.
- As briefly indicated in the examples given, sometimes controlling individual variables in a laboratory setting is invaluable, and sometimes it's best to do controlled data collection in a simulator or workplace.
- In our (ISS's) work with government and industry clients, we routinely get asked to consider very different questions, often involving dynamic data streams, and so alternative methods are necessary.

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Multi-Stakeholder Outcomes

- As one simple example, clients often require us to simultaneously assess fatigue-related metrics for:
  - compliance
    (e.g. against rules for work hours)
  - safety (e.g. incident levels by time of day corrected for exposure)
  - productivity (e.g. mining truck circuits completed per driver per 12h shift)

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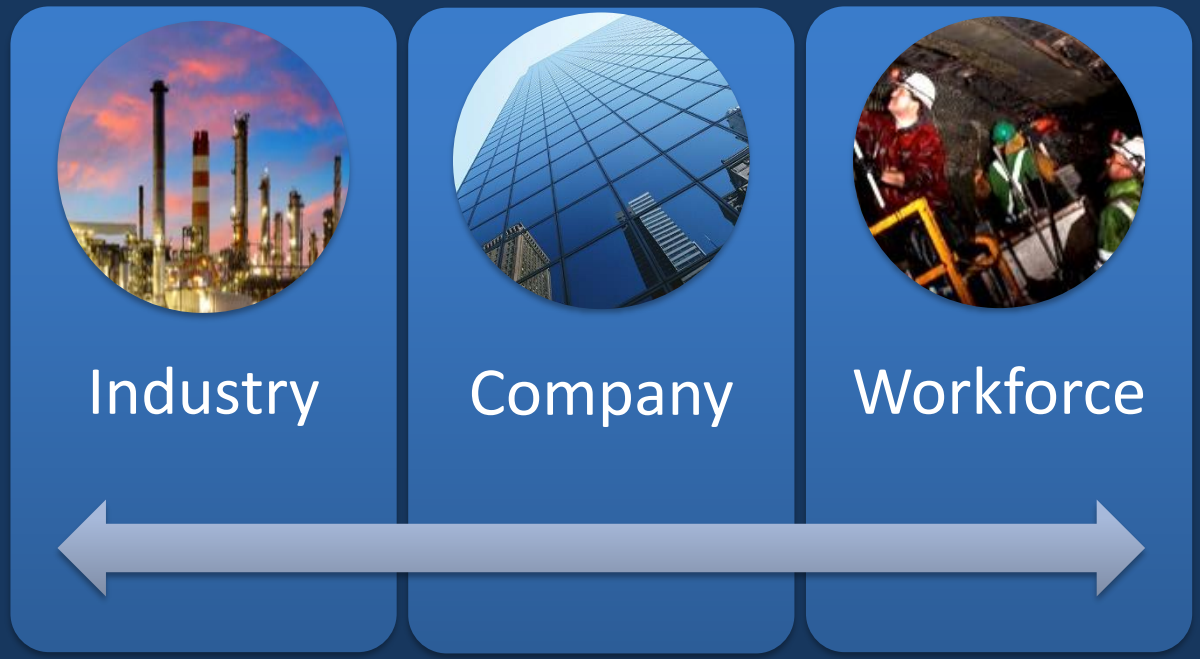
Multi-Stakeholder Outcomes



- At the same time, data is often coming from different scales: such as individual workers (e.g. fatigue hazard reports), the frontline workforce group (e.g. on-time performance of a public transport system) and even the industry (e.g. benchmarked compliance against flight & duty time limitations).

- To lead these projects we must combine context-specific constraints with multi-level variables, and work with leverage points in real-time dynamic systems, in a way that is valid and still practically useful.

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Astute Interventions

- The human system components (e.g. biological, psychological and social) and others (e.g. commercial, compliance, contextual), plus their relationships with each other, are practically and mathematically finite (while also being dynamically complex).
- These components are discoverable, discernable and demonstrable. When we know what to look for data can be gathered to assess the specific point in the complete dynamics that needs to be made visible. Focusing on the complexity within the client's business with relevance precision, avoids creating new distraction risks (i.e. meaningless metrics).

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Astute Interventions

- This approach allows the inclusion of scopes of impacts outside of operations, such as the positive impacts of reduced incidents on worker's families and communities, or impacts of company data to influence reviews of regulation, without losing the focus on employee safety, risk or productivity.
- The method we have been designing, testing and iterating, can work at various depths and scales to deal with what is valuable and/or feasible in an extended- or 24-hour work environment, from the workforce level up to the future direction of industry policy reform.

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Project Aims

- The primary aim of this project was to initiate the development a practical, visual approach to represent the elements of Fatigue Management, at any scale and over any timeframe of interest, for specific contexts.

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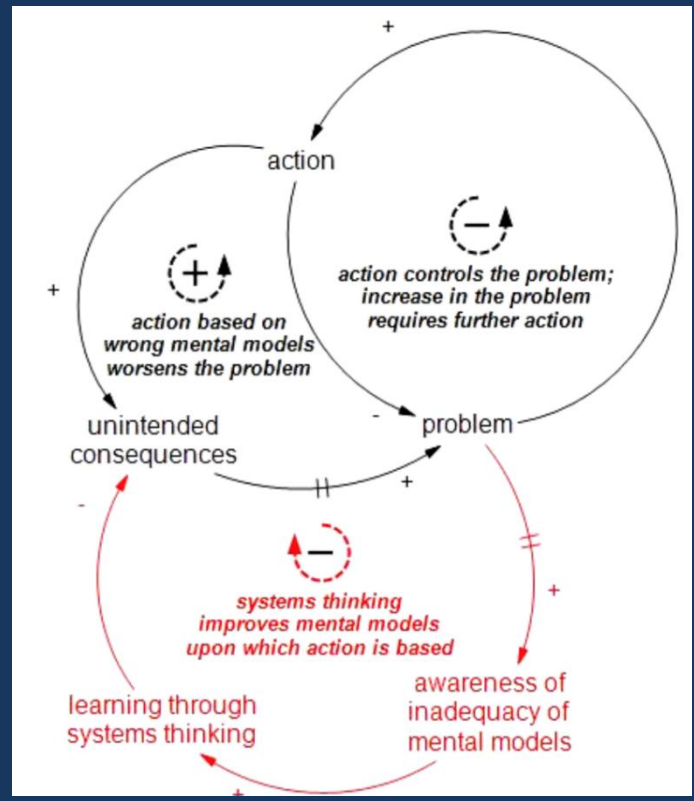
Project Aims

- The primary aim reflects an intention to support the acceptance of the full complexity of the field, while maintaining clarity in terms of the language, concepts and practicalities for those of us who have responsibilities to manage fatigue in workplaces.
- The model was to be developed as generic, but each application able to be highly nuanced, investigative and context-specific. Therefore, the results of client analyses are to be targeted and not necessarily generalizable to other situations.
- Despite the necessary complexity, the project ultimately aims to enhance the ability for industry to create the simplest data-driven solutions that generate the most measurable benefits in a multi-factor, multi-level, multi-benefits way.

Premise

The primary approaches used to systematically determine how fatigue-related factors, their inter-relationships, and scales of relevance could be identified and mapped were:



1. **Systems Research Efficacy:**
   e.g. Edson MC, Henning PB, Sankaran S (Eds.). A Guide to Systems Research: Philosophy, Processes and Practice. Springer: Singapore 2016; Volume 10.
2. **Causal Loop Analysis:**
   e.g. Kim D. Guidelines for Drawing Causal Loop Diagrams. The Systems Thinker 1992; 3(1): 5-6.
3. **Generative Systems Analysis:**
   e.g. Varey W. Apithology Systems Inquiry: Evaluation from a Generativist Ontology. Systems 2017; 5(22): 1-10.

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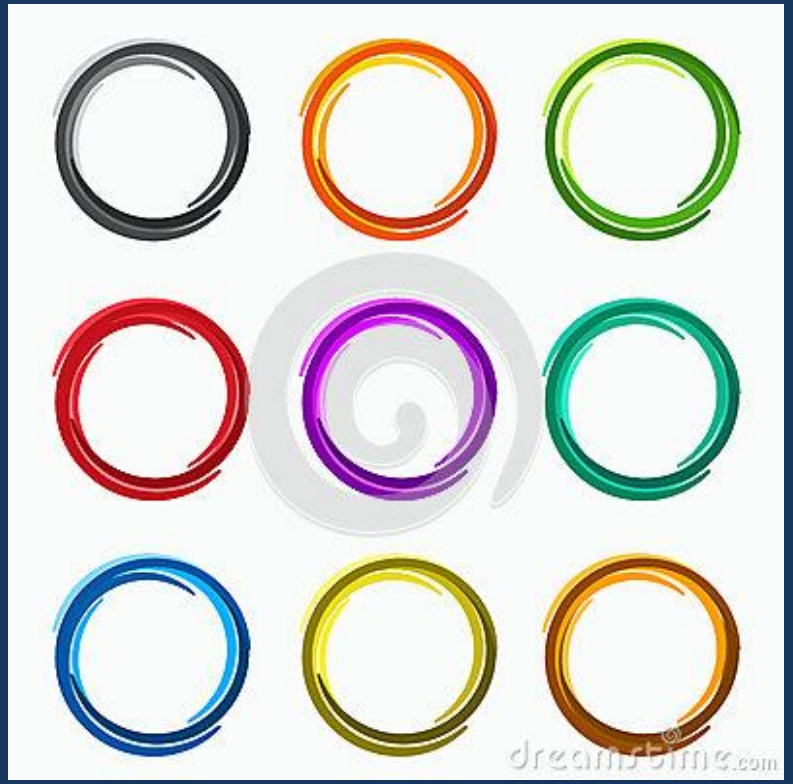
Method

1. Having seen human fatigue impacts in a wide range of environments over more than 20 years each, the authors were able to initially collate relevant examples of dynamics, at various scales. Looking at multiple scenarios led us to some essential truths and recurrent features.

2. As an example, one small set of initial dynamics related to what individual, family/household, social, workplace and other factors would need to be present to allow for a site's workers to focus not only on 'recovery' from work but also on 'preparation' for future work, plus the positive outcomes that could be enhanced due to increased prior sleep, etc.

Method

3. From the list of elements collated while developing a series of dynamic system maps, sub-elements were also derived, and analysis was then completed to determine criteria for evaluating each component to determine its apparent role in an archetype format related to fatigue.



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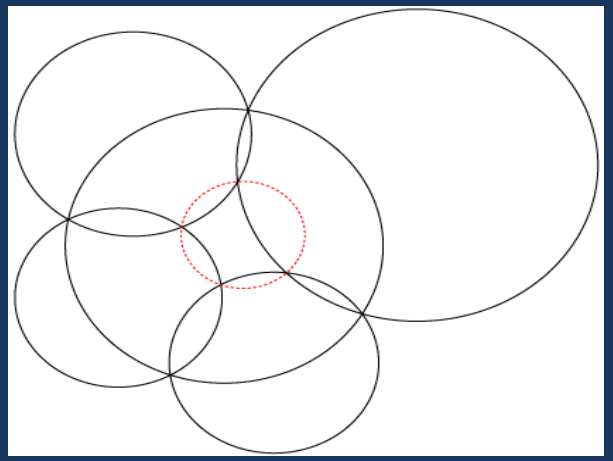
Method

4. The criteria used to isolate all the collated factors into the essential categories were that each had to be:



   A. Coherently distinct/discreet
      (e.g. coffee isn't considered different to Red Bull at the category scale of 'legal cognitive stimulants', which is a different category to 'illegal cognitive stimulants').
   B. Have one or more dependent relationships with other elements
      (e.g. in certain contexts the use of 'legal cognitive stimulants' may be related to both increased alertness at work and decreased ability to get to sleep quickly due to increased alertness after finishing work)
   C. Be commensurate at the appropriate scale or level
      (e.g. interventions at a small local site will not influence corporate processes, without additional elements being triggered).

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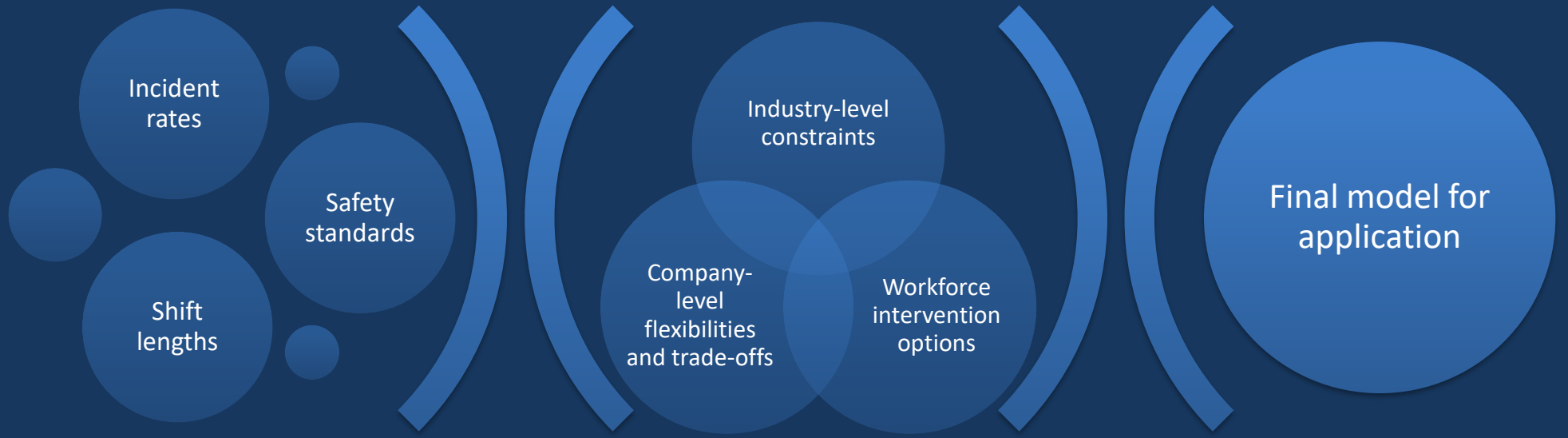
Results

- Having applied the above criteria the outcome of the iterative processing was a set of nine fatigue-related elements (with clusters of sub-elements to form three categories).
- Some example elements, and relevant variables or factors related to those elements, were:

1. Fixed Factors (e.g. geographic location(s), the 24-hour nature of the work demand)
2. Key Variables (e.g. duration of planned shifts, and regular overtime levels)
3. Industry-specific Drivers (e.g. optimal production volumes, regulated safety standards)
4. Feedback Relevance (e.g. incident rates for defined levels of incident severity)
5. Functional Thresholds (e.g. duration of night shifts beyond which incidents spike)

- The nine discreet elements when consolidated into three groups of three reflected: (a) Industry-level constraint parameters, (b) Company-level flexibilities and trade-offs and (c) Workforce intervention options (at work and in off-site situations such as commuting and at home).



Factors (later isolated into the nine Elements)

Elements and Categories (3x three-Element Categories)

For field validation and specific applications

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Results

- Structurally this created three elements at each of three different scales, and the relationships between them were further modeled and tested using a variety of systems dynamics research methods.
- A specific set of predicable causal relationships between the nine elements was determined at the generic level, but is pending field testing in data-rich scenarios that will not be detailed in this presentation. We plan on presenting detailed case studies on specific applications in the future.

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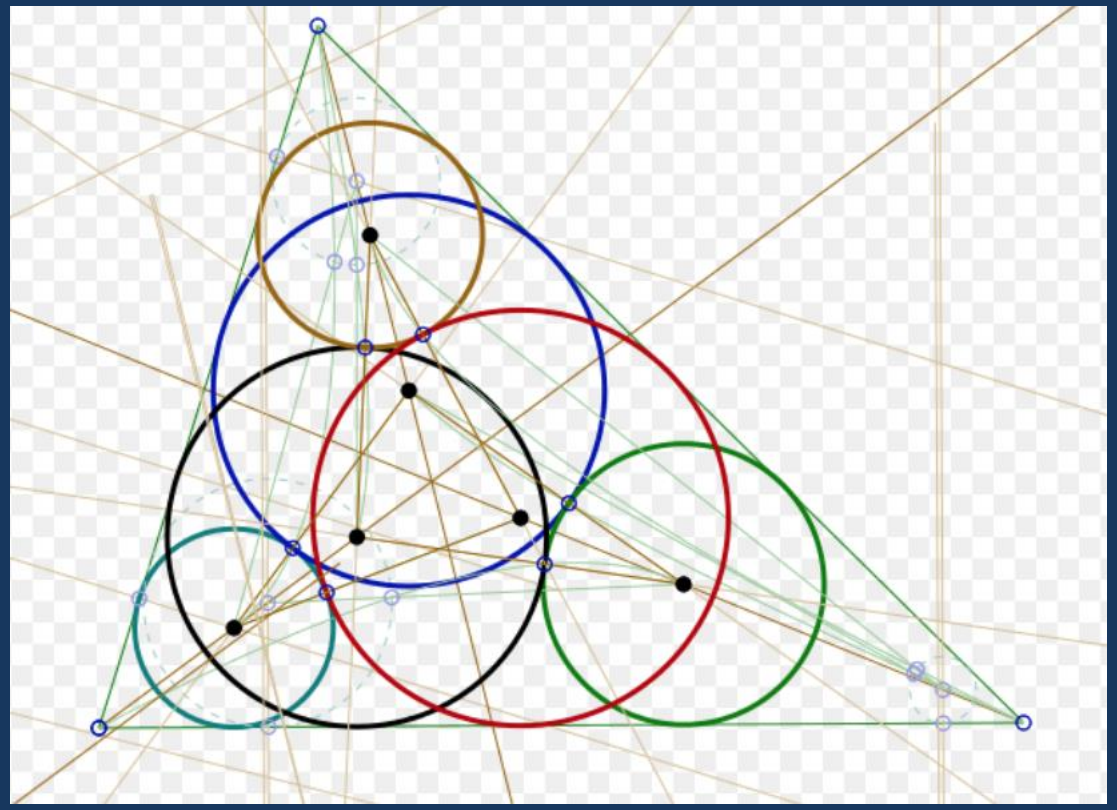
Model Refinement

- The iterative testing of the nine-element model involved experimentation with previously unresolved Fatigue Management scenarios to assess if the available metrics, data streams, thresholds, outcome measures of relevance, etc. all fitted within the model.
- The model was found to be valid, valuable and appropriate (e.g. at the correct scale).



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Model Refinement

- As far as can be determined to date the resulting approach and format allows for the visual representation of any cluster or clusters of Fatigue Management elements, to isolate dependent variables and intervention points of ‘whole of system health’ significance.
- For example, a visualized dynamic could be as small scale as the key variables and dynamics related to recovery sleep for an individual worker, or as large as the known health consequences of long-term shiftwork at a societal scale.

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Discussion

- For this paper we wanted to give you an early indication of our approach, which we believe will be shown to be methodologically rigorous, repeatable, and evidence-based for each industry sector it is applied to.
- The model initially allows us to practically help to lead clients away from any expectation that that one-factor interventions (e.g. reduce the weekly rostered work hours) will somehow attend to all related factors (e.g. current understaffing leading to overtime).

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Discussion

- This means that while we must make more complex models for clients, they are highly relevant, finite and more readily help to fulfil the shared aim of getting to the ‘sweet spot’ of effective change.
- As noted, results are always targeted to a specific client’s context, constraints, data streams, compliance requirements, and industry standards.
- Applications could therefore be as diverse as challenging the parameters within existing national hours of work regulations, or building a financial- and risk-based internal case to increase workforce numbers in order to allow measurable improvements in insurance and contingency management costs. We can’t currently identify any limits to the range of potential applications.

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Discussion

- The resultant approach is methodologically rigorous, repeatable and (pending additional validations with industry partners) evidence-based. What has been determined is that doing at least three-factor cross-scalar analysis reveals insights to see system dynamics that were previously neglected.

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Closing Statements

- From what we have determined, doing this analyses at three inter-dependent discrete scales (e.g. total workforce, corporation, industry sector) allows for high-resolution visual maps to be developed for any Fatigue Management context we have been able to conceive of.
- We believe that the benefits to Fatigue Management innovation will be significant.
- For some industry leaders, collaborators and policy regulators, the complexity of such an approach will be more than offset by the large and lasting potential benefits available from insights generated.

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