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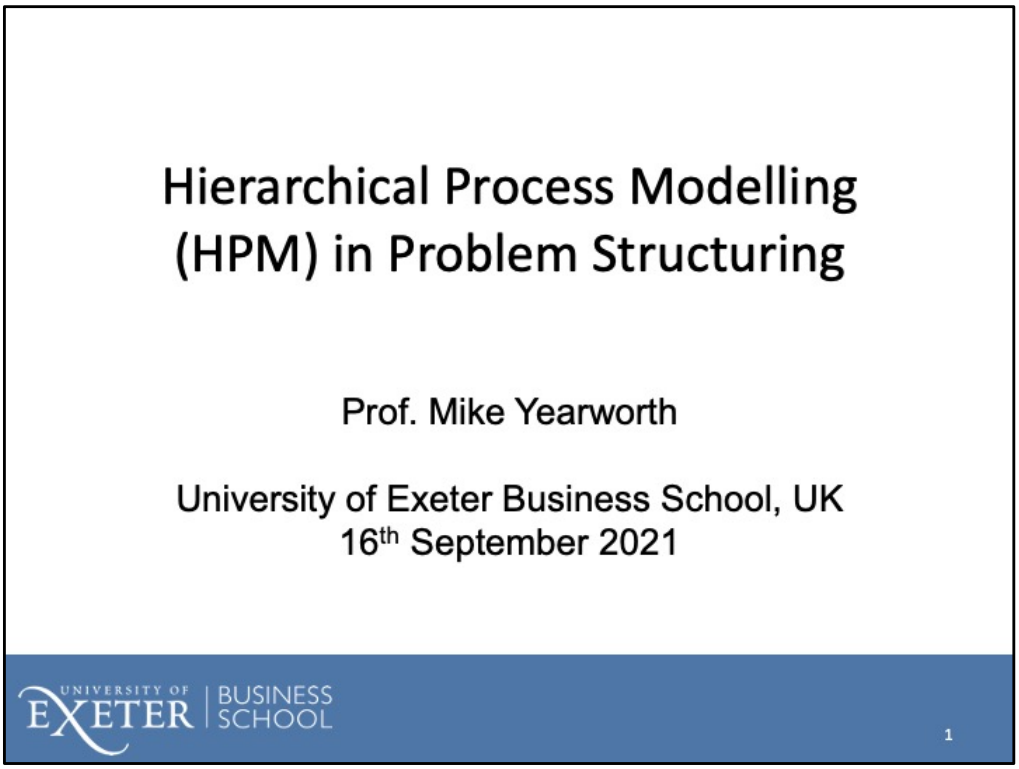
Abstract:

With its origins in the early 1990s as a functionalist approach to modelling engineered systems with explicit representation of uncertainty, Hierarchical Process Modelling (HPM) has gradually been incorporated into an approach to problem structuring where it fulfils a similar role to a model of purposeful activity in SSM. Its first appearance in this guise was published in 2010 in JORS. Since then, it has been taught to ~100 Engineering Doctorate (EngD) students as part of their programme in the EPSRC funded Industrial Doctorate Centre in Systems at the University of Bristol. It has also been applied as a PSM in two EU funded projects for energy and smart city planning where it was known as the STEEP Methodology - Systems Thinking for Efficient Energy Planning. The similarities and differences between this modelling approach and others used in PSMs are considered from the perspective of affordance and with particular reference to judgements of process performance using a simple visual representation of interval numbers as 'Italian Flags'.



Hi – I'd like to give an overview of the development of hierarchical Process Modelling and its use in problem structuring

Abstract

With its origins in the early 1990s as a functionalist approach to modelling engineered systems with explicit representation of uncertainty, Hierarchical Process Modelling (HPM) has gradually been incorporated into an approach to problem structuring where it fulfils a similar role to a model of purposeful activity in SSM. Its first appearance in this guise was published in 2010 in JORS. Since then, it has been taught to ~100 Engineering Doctorate (EngD) students as part of their programme in the EPSRC funded Industrial Doctorate Centre in Systems at the University of Bristol. It has also been applied as a PSM in two EU funded projects for energy and smart city planning where it was known as the STEEP Methodology - Systems Thinking for Efficient Energy Planning. The similarities and differences between this modelling approach and others used in PSMs are considered from the perspective of affordance and with particular reference to judgements of process performance using a simple visual representation of interval numbers as 'Italian Flags'.

Origins of HPM

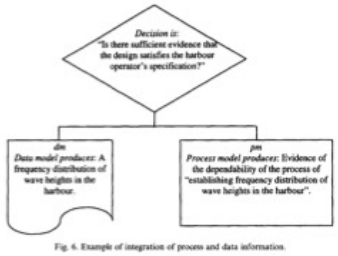


Fig. 6. Example of integration of process and data information.

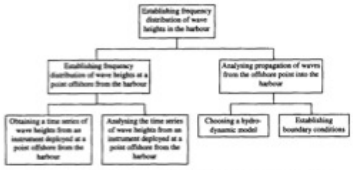


Fig. 7. Hierarchical model for establishing the dependability of a design process.

- Model of engineering systems as a process with a purpose
- Processes consist of sub-processes by a composition relationship
- Processes have an associated performance measure with explicit representation of uncertainty

Hall, J.W., Blockley, D.I., & Davis, J.P. (1998). Uncertain inference using interval probability theory. *International Journal of Approximate Reasoning, 19*(3-4), pp.247-264. doi: https://doi.org/10.1016/S0888-613X(98)10010-5

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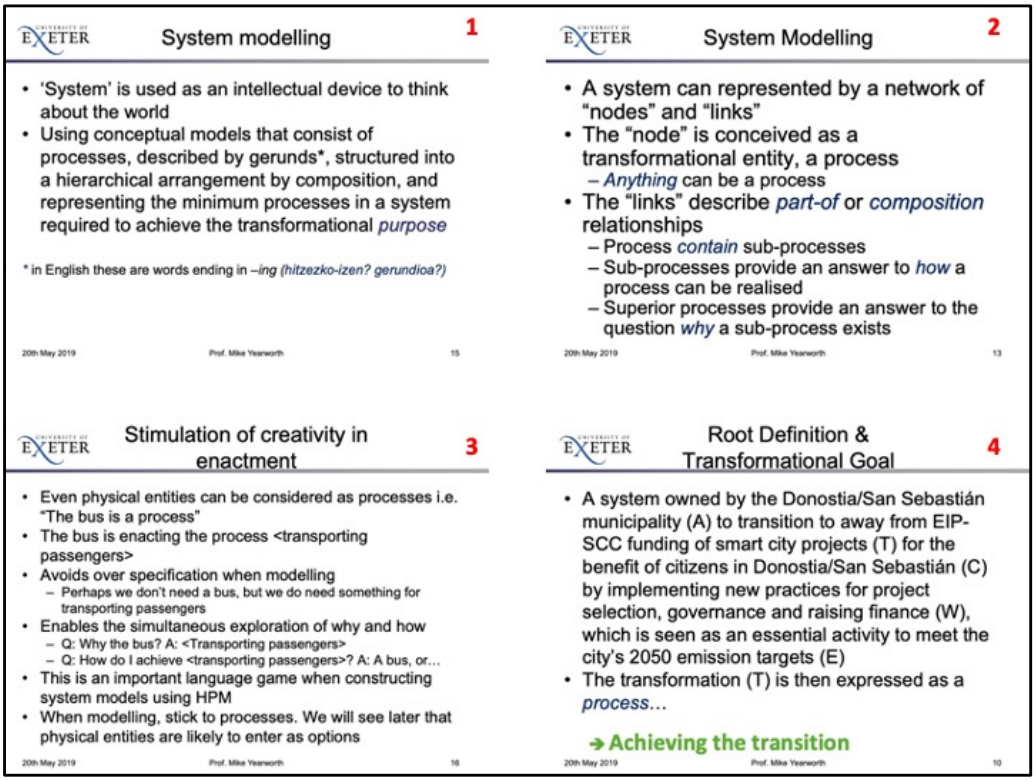
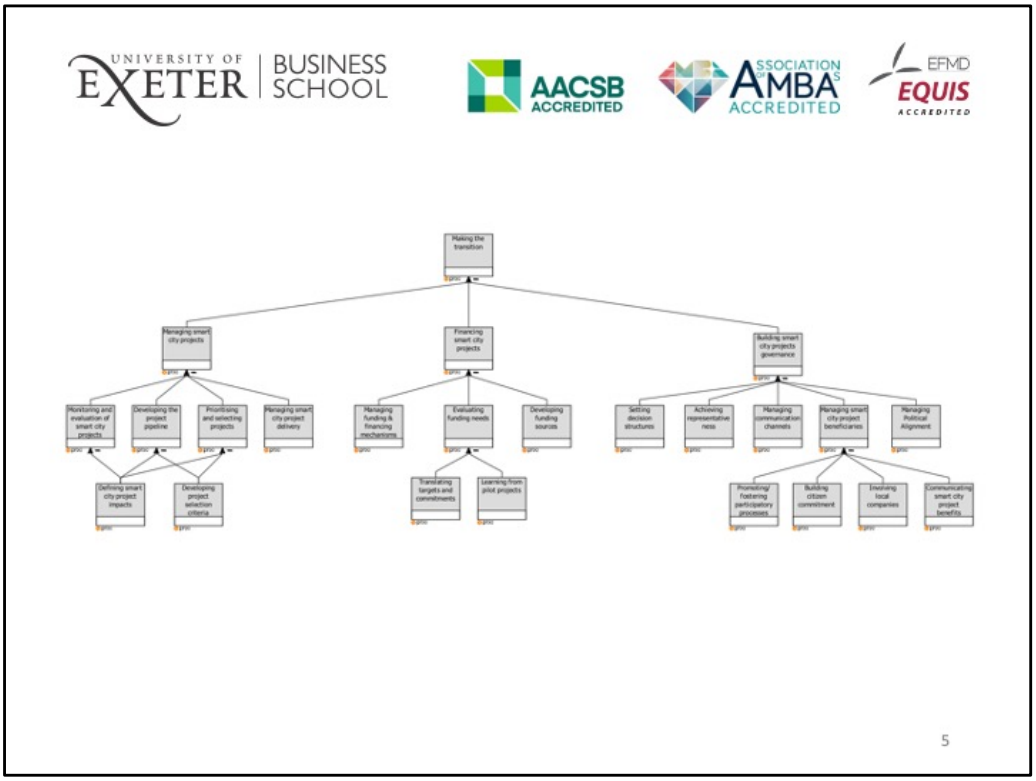
The origins of Hierarchical Process Modelling, or HPM, were first published by Jim Hall, David Blockley and John Davis in the Journal of Approximate Reasoning in 1998 and brought together interval probability theory, the means of combining evidence of process performance expressed as interval numbers, and their representation into a hierarchical structure of processes. That is, bringing process structure and evidence of process performance together into a single model. The motivation was driven by the need to model physical systems in civil engineering with a view to calculating their performance with explicit accounting for uncertainty of evidence or measurement. Note that David Blockley was sometime President of the Institute of Structural Engineers and Dean of Engineering at Bristol, and Jim Hall was sometime Director of the Environmental Change Institute at Oxford. John Davis was Professor at Bristol and introduced me to HPM when I joined the Systems Centre there in 2009.

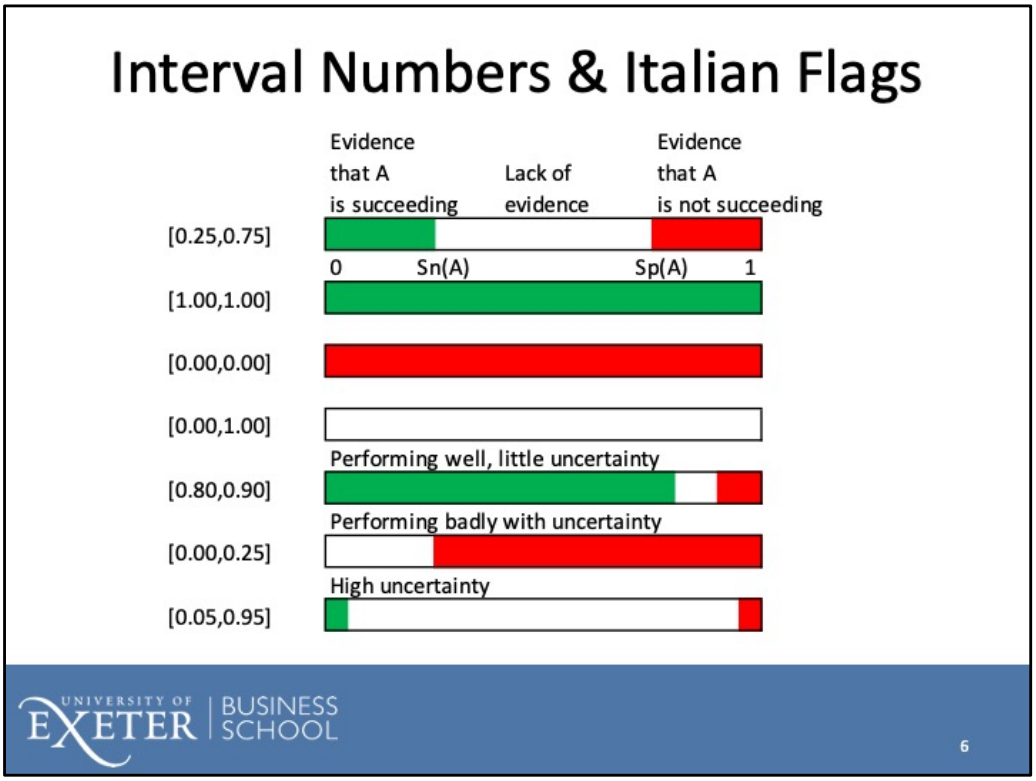


So, what exactly is a Hierarchical Process Model and how can it be used in Problem Structuring? In the interests of time these four slides summarise the approach and are taken from an introduction to a workshop I facilitated in San Sebastian in 2019 where I took a multi-organisation stakeholder group through a group model building exercise using HPM. There are 4 key points. The **First** thing to note is that I mean system here fully in keeping with how it is used in Soft Systems Methodology. HPM has a strong process ontology where everything and anything in the model is a process described by gerunds, not simply verbs. I'll come onto why gerunds are used in a bit. **Secondly**, transformations are enacted by processes, and if more detail is required then we can look inside a process to see detail about **how** it is enacted. What we find are more processes. **Why** a process exists can be answered by looking upwards in the model. **Thirdly,** Even physical things can be modelled as processes and this example here of the bus as a process enacting transporting passengers is an example of delayed reification, which has been found to be a useful approach when modelling**. Fourthly**, we can use HPM to model the transformation from a pretty-normal looking root definition – in this case a change project in the municipality of San Sebastian to move away from EU funding of smart city projects with a world view that this can be achieved through developing new practices for project selection, financing and governance.

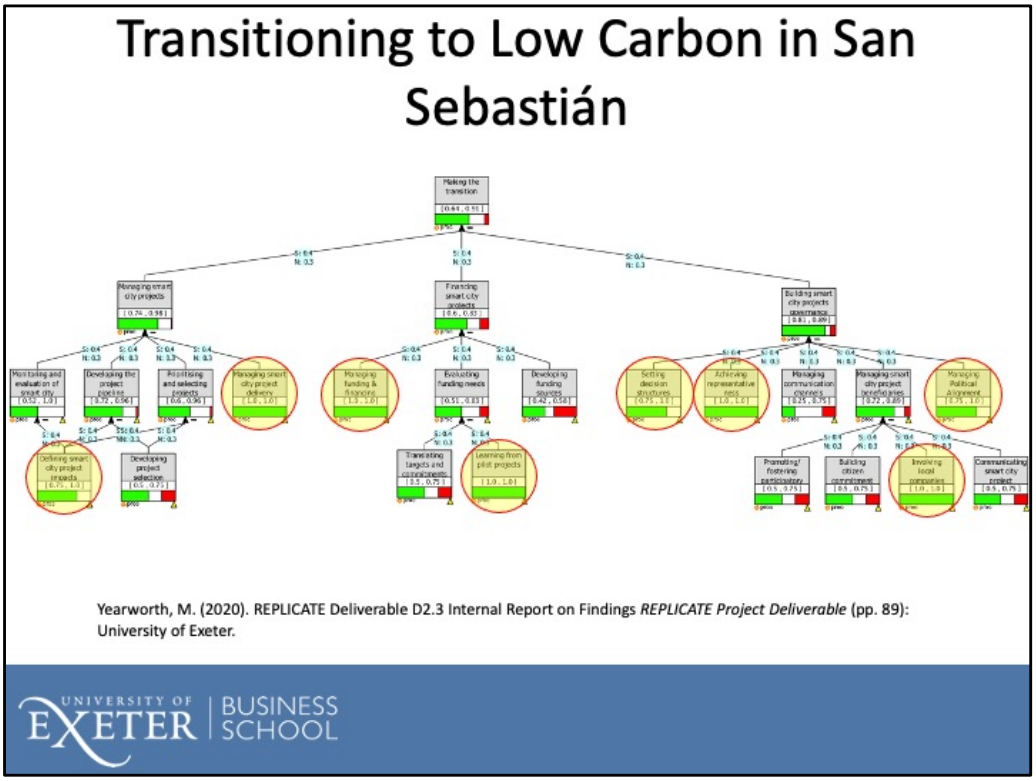
The group model building proceeded using nothing more than post it notes for processes and flip charts, or indeed table-tops, to manage their arrangement into hierarchical structure.



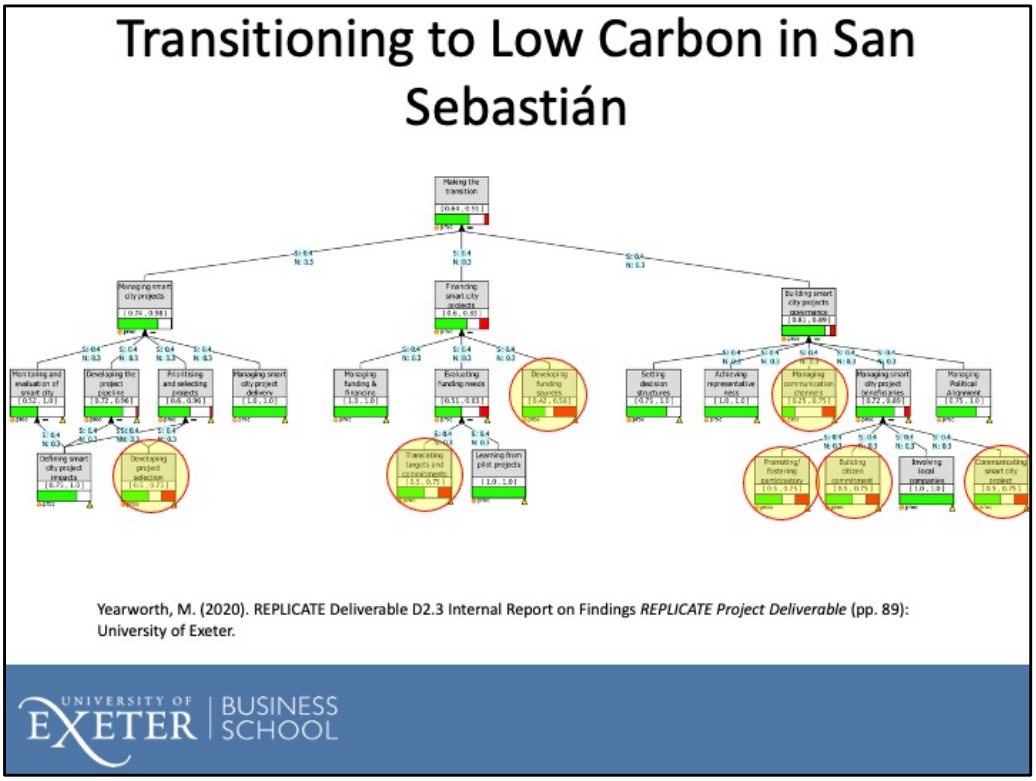
Here is the HPM from that San Sebastian workshop where the post-it note processes and hand-drawn containment links have been re-drawn using a software tool called Perimeta. This tool enables me to combine the process structure with the measurement model. To do this requires some knowledge of interval numbers and their graphical representation as Italian flags.



The intervals used in HPM mathematics are closed intervals. The mapping onto the Italian Flag is quite straightforward. Green is used to colour the range corresponding to evidence that the process is succeeding or performing well, red that it is not succeeding or performing badly and white to indicate lack of evidence and hence uncertainty. In the past these numbers have been generated from measurements and were used for calculating overall system performance. However, as HPM has been re-purposed to support problem structuring the colouring is used as a judgement or estimation of process performance elicited from participants during a workshop. The numbers on the left are the exact interval shown by the flag but can be ignored as a legacy.



Here's that San Sebastian model again, but this time with the participants' self-judgment of process performance. The 'green' processes are obviously judged to be performing well.



However, I've ringed the processes that seem to be performing less well and where there is uncertainty. These are the focus processes for action planning. The important thing to note here is that although I have used the full glory of the Perimeta software to draw the model and show the propagation of evidence to an overall figure of merit for system performance I've actually completely ignored it. The important thing for action planning are the judgements about process performance and these were converted to Italian flag representations using a 2-D Likert Scale Chart

The process performance has been evaluated with ...	Judgement of Process Performance				
	Very poor performance	Poor performance	Neutral performance	Good performance	Very good performance
Very low uncertainty	[0.00, 0.00]	[0.33,0.33]	[0.50,0.50]	[0.67,0.67]	[1.00,1.00]
Minor uncertainty	[0.00, 0.25]	[0.25,0.50]	[0.42,0.58]	[0.50,0.75]	[0.75,1.00]
Moderate uncertainty	[0.00, 0.50]	[0.17,0.67]	[0.25,0.75]	[0.33,0.83]	[0.50,1.00]
High uncertainty	[0.00, 0.75]	[0.08,0.83]	[0.17,0.83]	[0.17,0.92]	[0.25,1.00]
Very high uncertainty	[0.00, 0.83]	[0.00,0.92]	[0.00,1.00]	[0.08,1.00]	[0.17,1.00]

Figure 4. Italian Flag scoring schema for assessing the 'coverage' of the VSM epistemology. Interval Numbers are shown for completeness.

Lowe, D., Espinosa, A., & Yearworth, M. (2020). Constitutive rules for guiding the use of the viable system model: Reflections on practice. *European Journal of Operational Research, 287*(3), pp.1014-1035. doi: https://doi.org/10.1016/j.ejor.2020.05.030

The horizontal axis is basically our judgment of process performance, ranging from very poor performance (in red) to very good performance (in green). The vertical axis is the Uncertainty in the evaluation of judgment. In the top row we've got very low uncertainty so there is no white in any of the numbers. Going down to the bottom row we have very high uncertainty where basically the interval number is essentially all white. There are various ways this chart can be weighted, this example is drawn from a recent EJOR paper.

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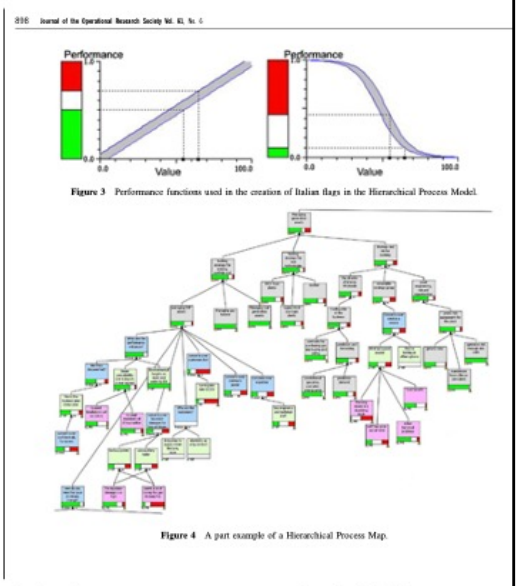


Figure 3 Performance functions used in the creation of Italian flags in the Hierarchical Process Model.

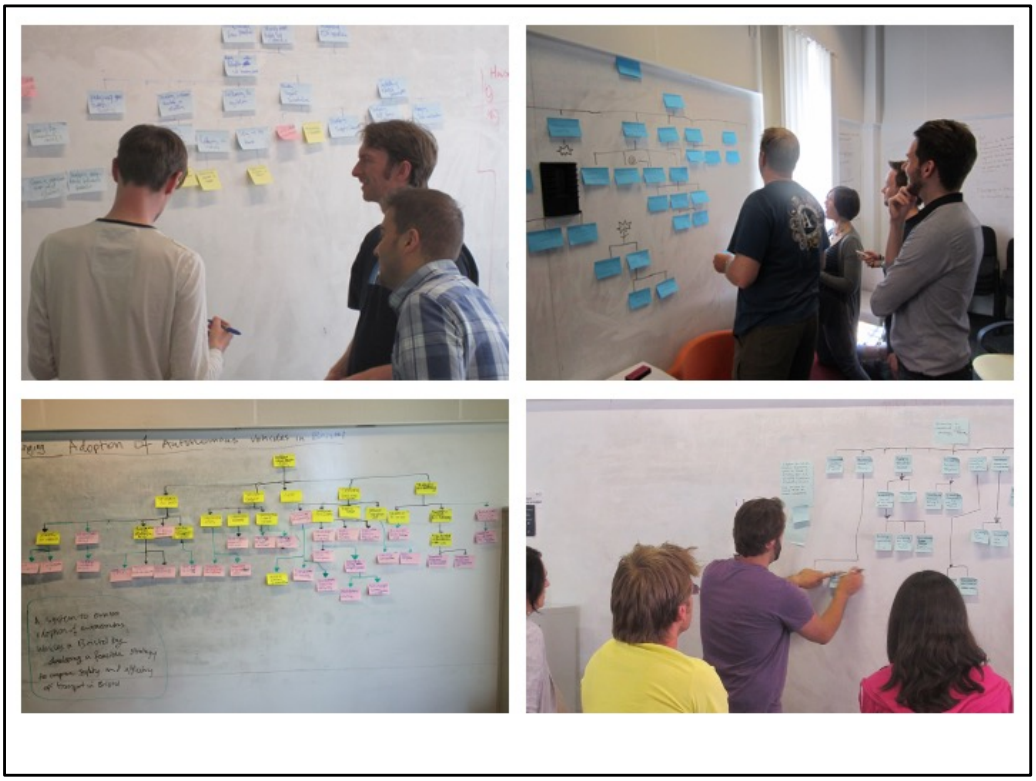
Figure 4 A part example of a Hierarchical Process Map.

Problem-structuring methods and project management: an example of stakeholder involvement using Hierarchical Process Modelling methodology

Davis, J., MacDonald, A., & White, L. (2010). Problem-structuring methods and project management: an example of stakeholder involvement using Hierarchical Process Modelling methodology. Journal of the Operational Research Society, 61(6), pp.893-904. doi: 10.1057/jors.2010.12

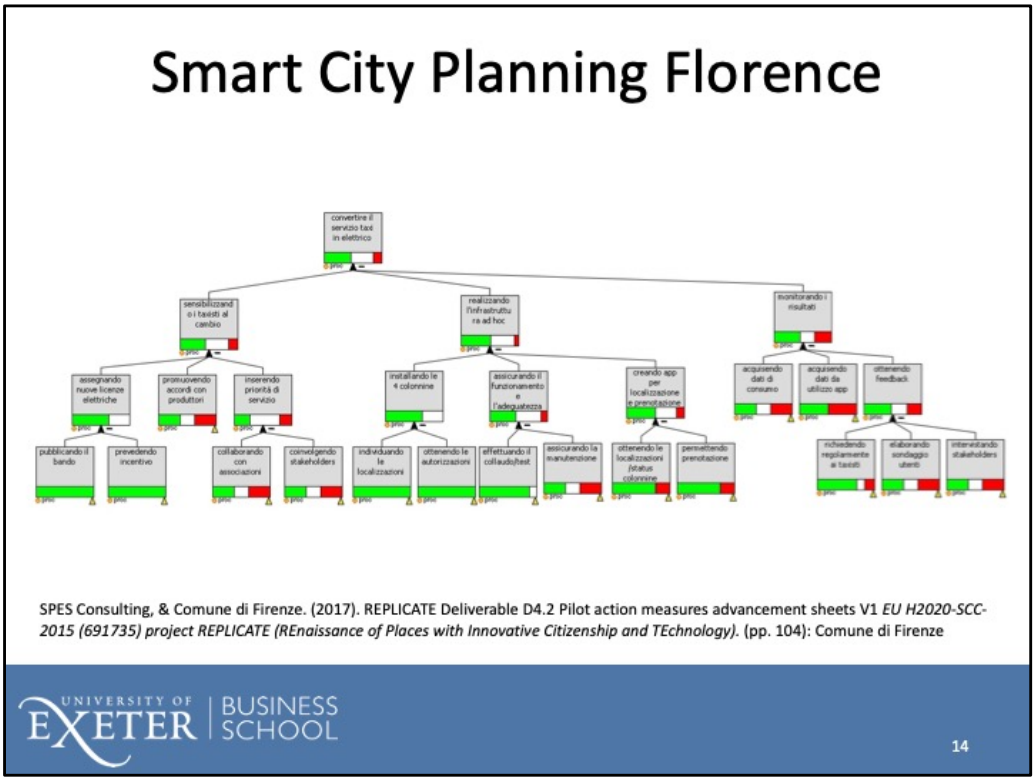
Around 2009 to 2010 the development of Hierarchical Process Modelling at Bristol took a turn towards the interpretivist. This work, published in the Journal of the Operational Research Society in 2010 marks an Interpretivist turn incorporates the hierarchical process model into a problem structuring method. This was the first outcome from the collaboration between the departments of Civil Engineering and Management at Bristol through the participation of Leroy White. John Davis was starting to use hierarchical process modelling to support his consulting engagements with industry and shown it could be used to model what is essentially a purposeful activity rather than a physical system. It was this work that drew Leroy into conversation with the civil engineers. I believe this was the genesis of the use of HPM in a problem structuring method.

These photographs are taken from the training course delivered in Bristol in 2013 for the EU funded Systems Thinking for Energy Efficient Planning or STEEP project. This is from the project kick off and we have teams from the municipalities of Bristol, San Sebastian and Florence. The training course was filmed, edited, and hosted on the STEEP project website from 2013 to 2021. A challenge was the project needed an approach that could be largely self-facilitating in each city because there was not the budget or time available for me to facilitate workshops in the three cities on an ongoing basis, although I did in fact end up facilitating workshops in in Bristol and San Sebastian. However, the intention was to hand this methodology over to the collaborating partners in Florence and Sebastian with a view to them being able to use the methodology themselves and especially to enable multi-organizational group workshops in native language i.e. in Italian and Basque. The technique of hierarchical process modelling is quite teachable. The how/why dialectic proceeds very intuitively once the root definition and its worldview is agreed.



The same training was also delivered to all of the Engineering Doctorate students that passed through the Engineering Doctorate in Systems Program at Bristol. By the end of the EPSRC funding for this program we had graduated 100 Engineering Doctorates. The bibliography at the end of this talk includes some of the published outputs that used HPM.

These photos are from one of the Bristol workshops. One of the things you can see from all of these workshop photos is that the construction of Hierarchical Process Models through group model building is easily achieved with post-it notes and whiteboards or flipcharts - software is not required.



Here is an example of HPM in use by the Comune di Firenze, one of many from the REPLICATE project, the successor EU project from STEEP. This shows the process for the migration of the taxi fleet in the city to electric vehicles – covering such processes as e-vehicle procurement, licencing, and building out the charging and monitoring infrastructure. The modeller, someone I have trained, has stuck to gerunds throughout – except at the top-level process, I think reflecting the fact that they see the change process as being finite. However, as a means of identifying problems with the change process and directing action it has fulfilled its purpose. Think of this model the next time you take an e-taxi in Florence.

Comparative Affordances

Property	HPM – PAS	SSM – PAS
Expression of Activity	Gerunds Verbs ending *–ing* --> have a sense of not completing	Verbs Actions can complete → sequences and loops
Feedback control	Each process has performance attribute Monitoring and controlling within the system	Monitoring and controlling action at next level up. Also see Kotiadis et al (2013) in JORS.
Boundary	Hierarchical by downward containment. Boundary exploration upwards	Hierarchical by downward containment. Boundary exploration upwards
	No Explicit System Boundary Uncertainty in top level process (white) captures incomplete knowledge of system	Explicit System Boundary
Formalism	Directed Acyclic Graph (DAG) Original need for calculation, no loops!	Informal Loops are possible
Acting	Action through fix (red) and/or find-out (white)	Action through comparing model with real world
Heuristics	7±2 heuristic Necessity, sufficiency, dependency between processes	7±2 heuristic, arises from 'The magical number 7±2' (Miller, 1956)
Application (referent)	Process (e.g. MAC), Project (e.g. JORS), Change Process (e.g. STEEP, REPLICATE), 1:1 Consultancy (e.g.CoME/EASY)	Many
Group Model Building	Yes	Possible
Tools	Perimeta, strategyfinder, IBIS. Online Same Time/Different Places (STDP) (Yearworth & White, 2019)	Possible

15

This is the crux of the paper in terms of relating HPM to the more familiar purposeful activity system modelling approach in SSM. I'll try and step through this table of comparative affordances quickly…

Comparative Affordances

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Group Model Building	Yes	Possible
Tools	Perimeta, strategyfinder, IBIS. Online Same Time/Different Places (STDP) (Yearworth & White, 2019)	Possible

16

Perhaps the biggest difference is the use of gerunds rather than verbs to express activity. In examples of purposeful activity system modelling in SSM that I've seen, verbs express activities that can complete, whereas the gerund form suggests ongoing-ness. This reflects its strong process ontology arising from its origins in structural engineering – one would expect a process like "being a structural support" to be an activity one would hope never completes. Whilst this may seem to preclude certain types of applications, I don't think it does in practice. It is well suited to the iterative and ongoing nature of the ideal of problem structuring methods. I therefore see this as a strength.

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17

The feedback control to ensure that the system is doing what was intended i.e., monitoring and controlling activity, is quite explicit in SSM modelling usually appearing at the outermost level of the model. In HPM it is embedded within the model itself, both with explicit representation of the performance of every process but also with explicit modelling of monitoring and controlling processes at whatever level of detail is required. However, there is a very interesting paper from Kathy Kotiadis and co-authors published in JORS in 2013 that comes quite close to the combination of modelling process structure with process performance expressed in the original 1998 HPM paper that I referred to at the start of the talk.

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18

The idea of system boundary is both similar and different. It is similar in that more detail about activity can be found by delving into, or within a process – something I've called downward containment. And boundary exploration can be achieved by going in the opposite direction. The only real difference is that in HPM we do not explicitly draw a boundary around a system. Perhaps there is a more idealised sense of the model being the system and therefore doesn't require it.

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Group Model Building	Yes	Possible
Tools	Perimeta, strategyfinder, IBIS. Online Same Time/Different Places (STDP) (Yearworth & White, 2019)	Possible

19

As far as I can tell from reading SSM literature, and especially Systems Thinking Systems Practice, there was never any particular formalism invoked or required to develop purpose activity systems models. I am more than happy to be corrected on this point. However, HPM did emerge from a very formal set-based approach to the combination of evidence from process performance measures and therefore must be restricted to directed acyclic graphs – i.e., there are no loops. Whereas in SSM loops are possible. This is not a loss in HPM as the strong process ontology that treats all activities as ongoing processes does not require them.

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Group Model Building	Yes	Possible
Tools	Perimeta, strategyfinder, IBIS. Online Same Time/Different Places (STDP) (Yearworth & White, 2019)	Possible

20

Action in SSM is through comparison of the model with what is happening in the world. SSM is well-developed in this regard with the excellent models from Checkland of the intertwining of inquiry into the world and the world doing its thing. With HPM we have been on quite a long journey, shifting away from a functionalist interpretation of models towards the interpretivism of SSM. The current approach of focussing on the red processes 'to fix' and the white processes 'to find out more' is perfectly workable in practice but does need further development theoretically.

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Tools	Perimeta, strategyfinder, IBIS. Online Same Time/Different Places (STDP) (Yearworth & White, 2019)	Possible

21

The 7±2 heuristic in SSM arising from Miller's 1956 paper in the Psychological Review can also be applied to HPM for the same reasons. However, it also arose as a consequence of the original way that evidence was combined through calculation. It was found that the default necessity and sufficiency conditions arrived at through trial and error in consulting engagements, actually forces model structure with not too-many subprocesses. Very broad process models not only broke the algorithm they were difficult to understand for the same reasons. This is a useful heuristic that's shared between the two modelling approaches.

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22

Of course, SSM has been widely applied so there is no need for me to explain more. I have included a bibliography at the end of my talk that lists some of the published applications that you can follow up if interested.

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Formalism	Directed Acyclic Graph (DAG) Original need for calculation, no loops!	Informal Loops are possible
Acting	Action through fix (red) and/or find-out (white)	Action through comparing model with real world
Heuristics	7±2 heuristic Necessity, sufficiency, dependency between processes	7±2 heuristic, arises from 'The magical number 7±2' (Miller, 1956)
Application (referent)	Process (e.g. MAC), Project (e.g. JORS), Change Process (e.g. STEEP, REPLICATE), 1:1 Consultancy (e.g.CoME/EASY)	Many
Group Model Building	Yes	Possible
Tools	Perimeta, strategyfinder, IBIS. Online Same Time/Different Places (STDP) (Yearworth & White, 2019)	Possible

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HPM has been used quite successfully by groups. Both in traditional Same Time/Same Place workshops, with participants clustered around flip charts and white boards using post-it notes and also online using Group Support Systems. More on this next. I am less clear about group model building in SSM. I think I am on reasonable grounds in thinking that group model building and SSM come together in the literature where there has been some reference to multimethodology – for example in PartiSim or bringing SSM and System Dynamics together.

Comparative Affordances

Property	HPM – PAS	SSM – PAS
Expression of Activity	Gerunds Verbs ending *–ing* --> have a sense of not completing	Verbs Actions can complete → sequences and loops
Feedback control	Each process has performance attribute Monitoring and controlling within the system	Monitoring and controlling action at next level up. Also see Kotiadis et al (2013) in JORS
Boundary	Hierarchical by downward containment. Boundary exploration upwards	Hierarchical by downward containment. Boundary exploration upwards
	No Explicit System Boundary Uncertainty in top level process (white) captures incomplete knowledge of system	Explicit System Boundary
Formalism	Directed Acyclic Graph (DAG) Original need for calculation, no loops!	Informal Loops are possible
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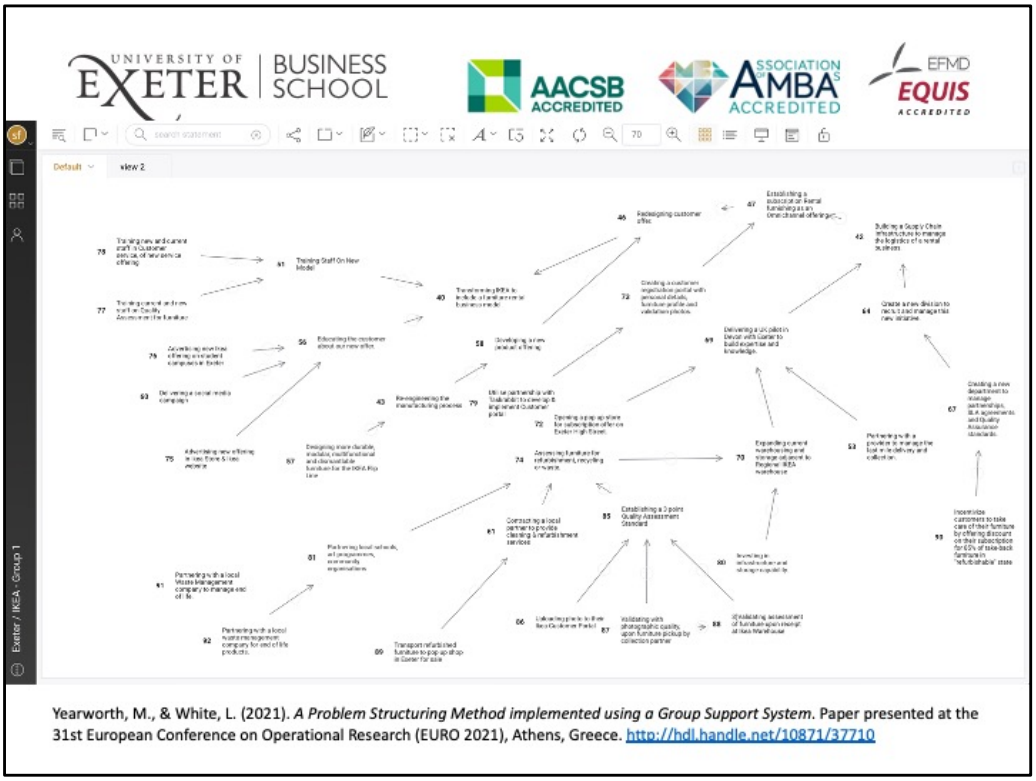
Group Model Building	Yes	Possible
Tools	Perimeta, strategyfinder, IBIS. Online Same Time/Different Places (STDP) (Yearworth & White, 2019)	Possible

There is no reason why either HPM or SSM need any form of IT tool support in order to be applied. HPM has a software tool called Perimeta mainly because of its origins to calculate system performance and that requires implementation by an algorithm. However, it has been possible to implement HPM online using a Group Support System. General purpose tools like Miro and Mural can be used, as, after all, an HPM in a Same Place/Same Time workshop is just post-it notes with lines. However, Both Miro and Mural are a little too general-purpose and will let participants do all sorts of other things at the same time and don't support a specific modelling formalism. I have however used Colin Eden and Fran Ackermann's strategyfinder system to develop HPMs in Same Time/Different Places workshops to great effect with my MBA students and also in another EU project.



Yearworth, M., & White, L. (2021). *A Problem Structuring Method implemented using a Group Support System*. Paper presented at the 31st European Conference on Operational Research (EURO 2021), Athens, Greece. http://hdl.handle.net/10871/37710

This is an example of a hierarchical process model developed by one of my Operations Management student groups when our MBA programme was being delivered online. This was a case study looking at the servitization of IKEA's business model and the transformation towards furniture rentals and the circular economy. I presented this work at EURO in July and is available for download from the University of Exeter website. This work has been very successful on the whole. One of the main advantages has been that the technique is simple to learn and therefore the online groups can self-facilitate, a necessity given the spread of groups by timezone.

I know that this has been a very quick tour of hierarchical process modelling but you can download this presentation with my speaker notes from the link obtainable from this QR code or the URL beneath. I'll leave this slide up whilst I take any questions.

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Spare Slides

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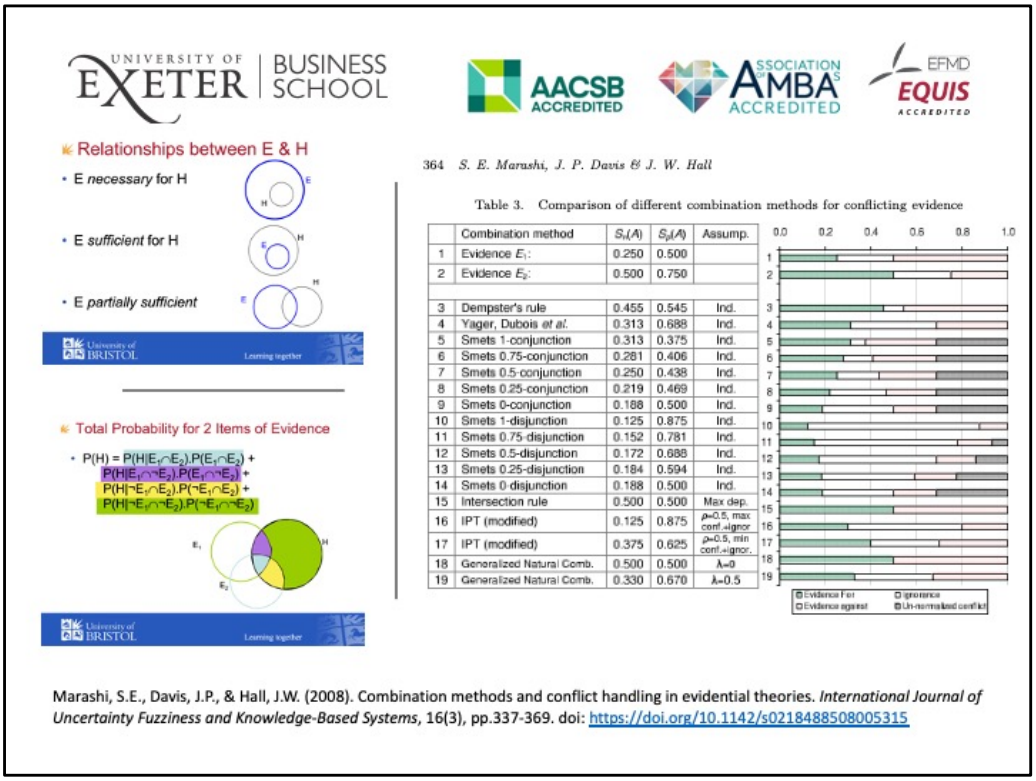
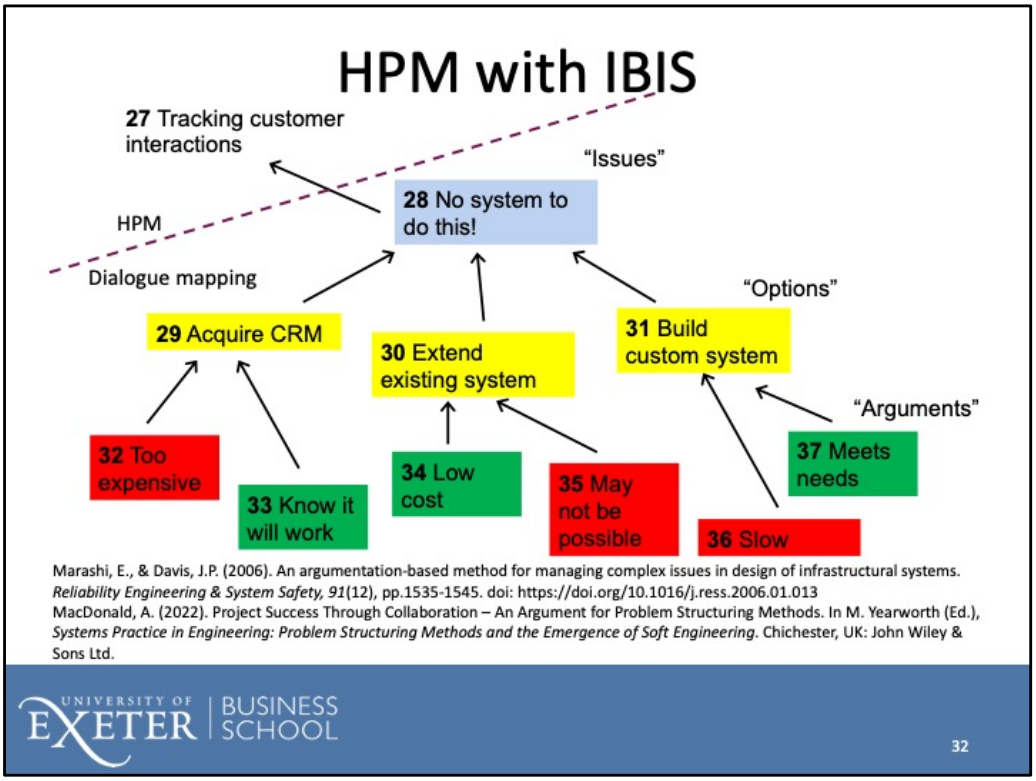
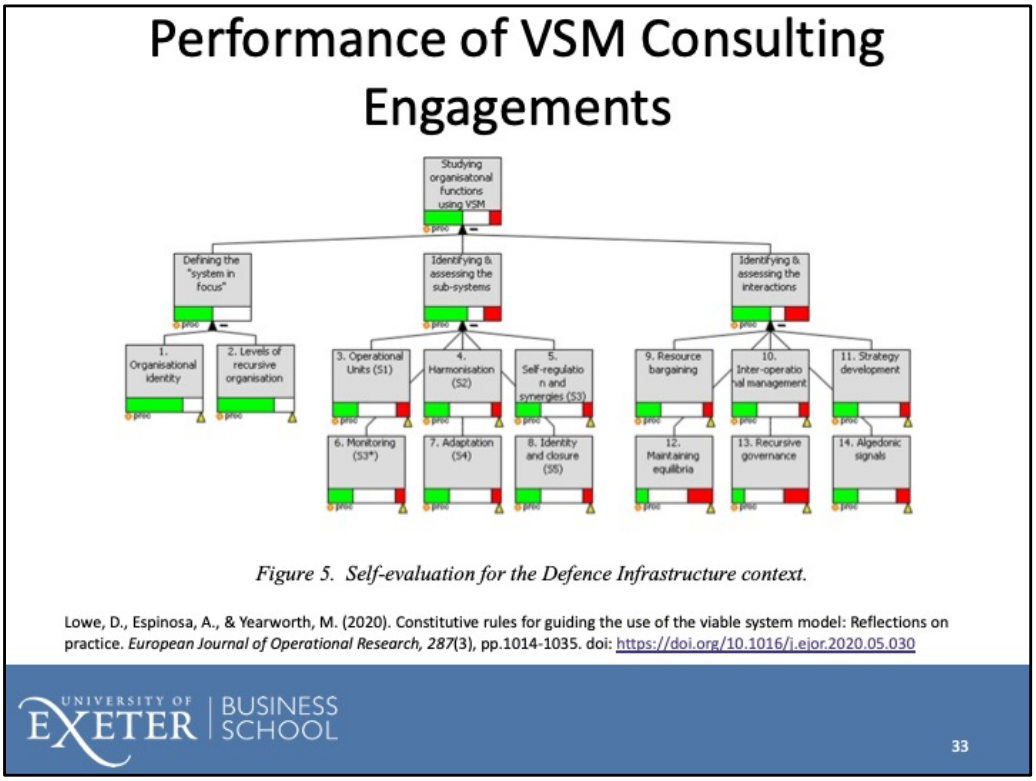


Marashi, S.E., Davis, J.P., & Hall, J.W. (2008). Combination methods and conflict handling in evidential theories. *International Journal of Uncertainty Fuzziness and Knowledge-Based Systems*, 16(3), pp.337-369. doi: https://doi.org/10.1142/s0218488508005315

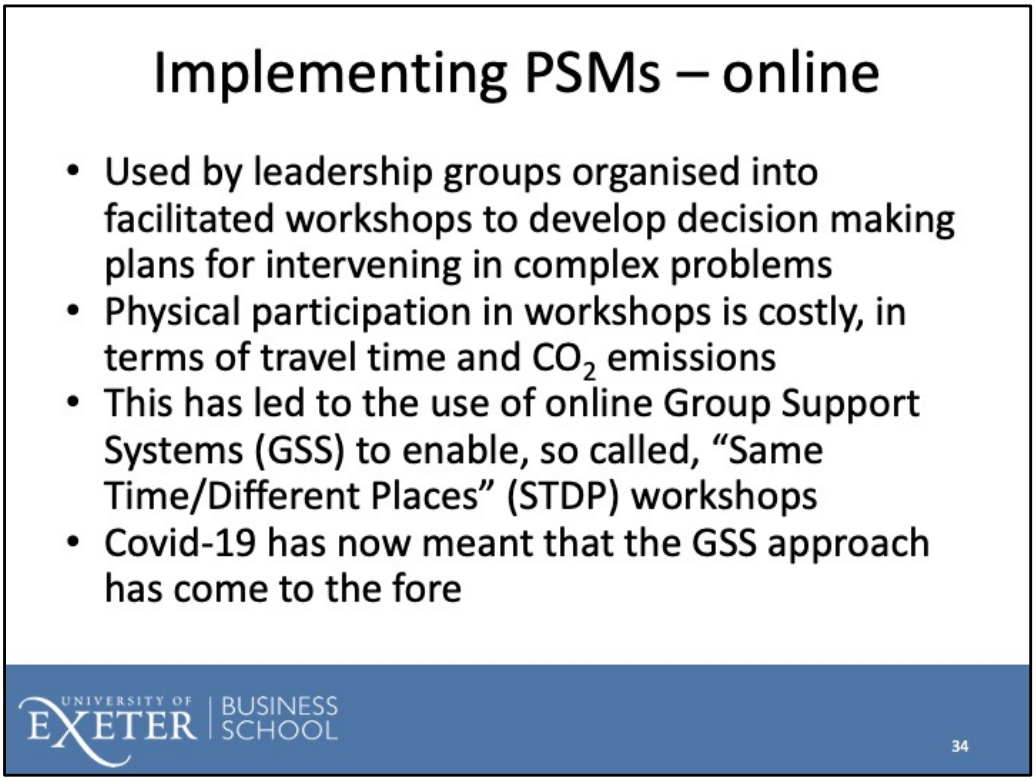
As an aside, a lot of the theoretical development in Hierarchical Process Modelling during the 1990s was involved with evaluating the different ways of combining measures or evidential beliefs about performance of processes into an overall performance measure for a system. Emad Marashi's PhD thesis led to the development of the Juniper algorithm, which was a compromise between these different techniques that was more suited to the messy consulting engagements of Civil Engineering. This was incorporated into the Software that was developed to support consulting engagements by capturing the process structure, the measurement model, and the calculation with its associated parameters.



The final thing I want to show you is that the HPM modelling approach has been extended by the addition of Issue Based Information Systems ideas by adding decoration to identify Issues, Options and Arguments. The essence of this extension is to recognise the Process to Issue boundary (shown dotted here) and to shift thinking to resolving Issues through the development of Options and then debating these through Arguments for and against. This is a trivial illustration from the training material given to my MBA class but there have been examples published and a good case study from the rail industry is under development for the book I'm Editing that should appear next year. In this example, the process "tracking customer interactions" is performing badly, it's a red process, because there is no system to do this – this is the issue at the limit of the decomposition of the process. The modelling has then been extended to develop a number of options to resolve the Issue with arguments for and against.



Hierarchal process modelling has also been used to performatively model VSM engagements where the self-judgment of on process performance is designed to focus the attention of the VSM practitioner on what needs to be improved. To develop this model, we followed Checkland's approach for specifying constitutive rules for Soft Systems Methodology but applied the idea to the use of the Viable Systems Model as a PSM. The model shown here is an expression of the constitutive rules as a purposeful activity model. It would be possible to do the same for SSM in HPM, although we've not done that as yet.



Physical participation of the members of stakeholder groups who are geographically separated is costly, both in terms of travel time and CO_2 emissions. Geographical separation could mean spanning continents. This has led to the use of online Group Support Systems to enable, so called, "Same Time/Different Places" (STDP) workshops. Now that Working From Home is just another form of spatial separation, The development of such group support systems means they are ideally suited to support lockdowns, social distancing or travel restrictions that characterise the context we are working in today.