Problem Solving

By

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Problem Solving—Finding and Organizing Data

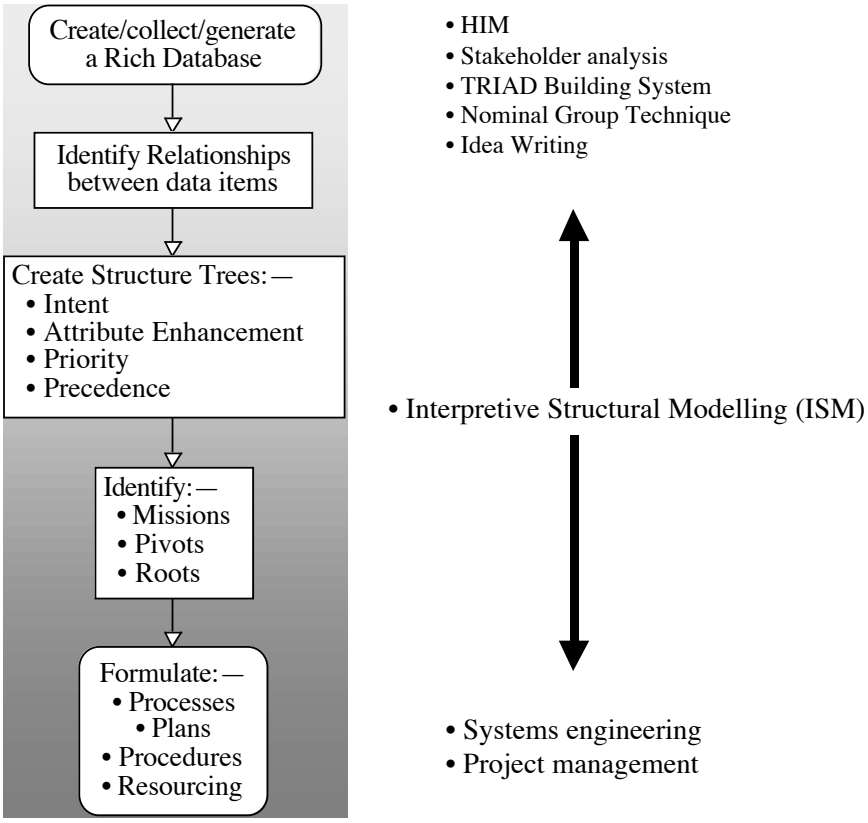


Figure 1. Tools for Purposeful Solving of Complex and Obscure Problems

Figure 1 shows how selected tools can be used to organize and manage information in the pursuit of solving problems. The tools, and examples of their use in action, will be shown below.

Idea Writing

Idea Writing is a group technique for extracting anonymous information. Anonymity is important, but not simple to guarantee. Anonymity prevents some ideas from being unduly reverenced simply because some senior person produced them, and prevents others ideas from being scorned because the author was junior—all without offending.

The process is deceptively simple. First a trigger question is formulated and agreed, e.g.

- "what do we want to achieve by when…",
- "how should we tackle…",
- "what are the most important aspects of…"

- "what are the attributes of a good solution"…

Choice of trigger question is fundamental. An effective trigger question is focused around "we", i.e. the group, not an individual. It is chosen to elicit a broad range of possible responses. Ideally, it looks towards future…

Idea Writing Procedure

A facilitator manages the group. Team members are given a sheet of paper and pencil and asked to write responses to a trigger question After 3/4 minutes, without warning, members are required to exchange their papers with others, not adjacent

Other members' work appears in front of individuals and triggers new ideas. After 2/3 minutes, the exchange process is repeated, and then again, sufficient to obscure the origin of any particular idea. Use of provided pencils avoids tracing idea ownership through different inks, etc.

Each member in turn then reads out one idea from his or her list for group discussion, omitting any idea already mentioned. The result is a rich list of ideas, discussed, understood and broadly agreed by the group

NB. Gives richer results than brain storming, which can be dominated by individuals

Nominal Group Technique (NGT)

A facilitator manages the group. NGT establishes a consensus view from the group.

NGT starts with a rich but unstructured set of ideas, attributes, etc. (e.g. from Idea Writing or Brain Storming). Each member is allocated marks:

- 10 for the idea they consider most important
- 9 for next most important, and so on…down to 1

Many ideas may receive no marks. The facilitator accumulates scores and produces a rank order list. This rank order list is then truncated to, say 20 items as agreed by the group: Truncation drops off ideas with little support. Items on the list are then discussed to ensure their meaning is clear to all. Finally, the rank order is rearranged if necessary provided there is *unanimous* agreement.

Result: Produces an ordered list of ideas to which all within the group subscribes.

N.B. NGT is valuable in producing consensus and in overcoming bias and prejudice. It also provides a basis for rudimentary data structure trees

Interpretive Structural Modelling

Develops so-called reachability matrices by:

- generating entities/objectives/projects/etc.
- taking entities in pairs
- asking questions "does entity A contribute to entity B, or is it the other way round, or do they both contribute to each other equally, or is there no connection?"
- a "yes" is entered as a "1", a "no" as a "0". There are 4 possible combinations

The completed matrix rows and columns are manipulated so that the entities are in sequence, e.g. with entities contributing most at one end, and with entities most

contributed to, at the other. Graph "trees" are drawn from the manipulated matrix. The trees reveal emergent properties and can be used to develop architecture and process.

ISM Trigger Questions and Viewpoints

The ISM technique can be used widely, and is very effective. It can, however, take some time, so use of a simple program to assist in the process may be helpful.

It is possible within ISM to ask different questions, evoking different results:

- Asking if Objectives "help to achieve" each other leads to Intent Structures
- Asking if attributes "contribute strongly" to each other produces Attribute Enhancement Structures
- Asking if Activities "precede" each other results in Precedence Networks
- Asking if Projects "are more important than" each other gives Priority Structures

N.B. Priority Structures are subjective, and must be associated with a set of rules by which "more important" is to be judged

The ISM process is subtle. Given a score or more factors, most groups find it very difficult, even impossible, to agree about priorities, structure, etc. ISM overcomes this by looking at only two factors at a time. This is much more manageable. Most people can readily agree about the relative merits of only two contrasting factors. The process of discussing all the factors two at a time also highlights misunderstandings, airs views and gradually develops a consensus within the group. Finally, the ISM process can be lengthy; this turns out to be useful, too, since it obliges reluctant members to come down of their proverbial fences.

Contribution Matrices

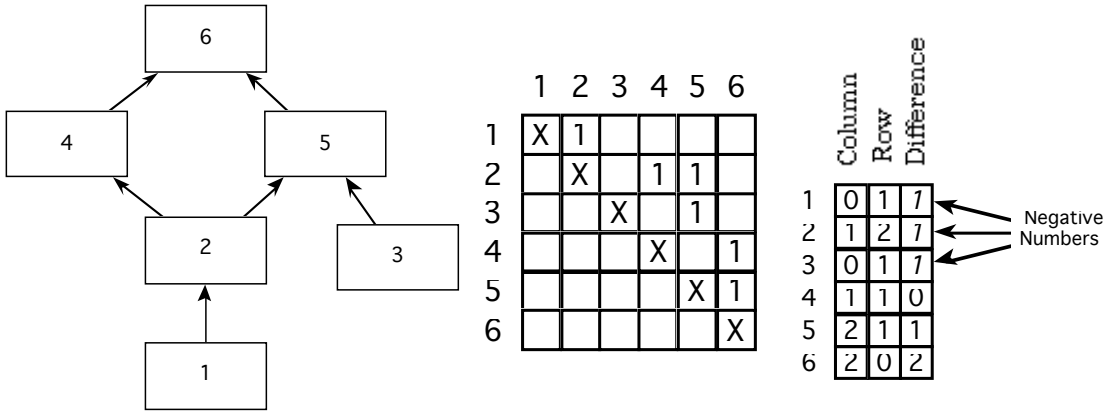
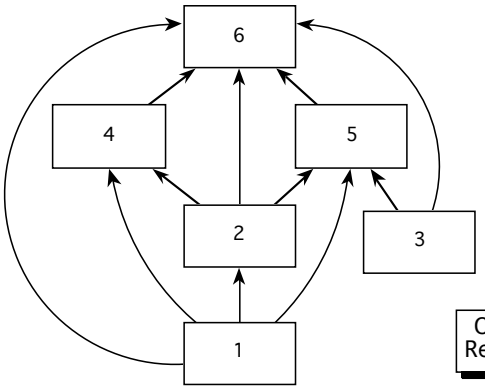


Figure 2. Contribution Matrices

To understand ISM, see Figure 2. At left is a simple tree of boxes with directional arrows. The tree can be represented in the matrix at centre, with each arrow shown as a '1'. It is also possible to sum the '1's in each column and each row, as shown at the right, and to take the difference between them. This last column shows the same numerical sequence

as the boxes at the left. This factor can be used in the automatic sequencing of disordered matrices.

Reachability



	1	2	3	4	5	6
1	X	1	0	1	1	1
2	0	X	0	1	1	1
3	0	0	X	0	1	1
4	0	0	0	X	0	1
5	0	0	0	0	X	1
6	0	0	0	0	0	X

Concept of Reachability

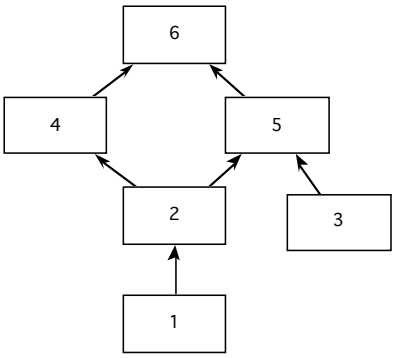


Figure 3. Reachability. Arrows at left, and the matrix, show which boxes can be reached from which—illustrating Reachability. Conventionally, each box is considered "transitive" and is represented as at right

Developing Intent/Attribute Structures

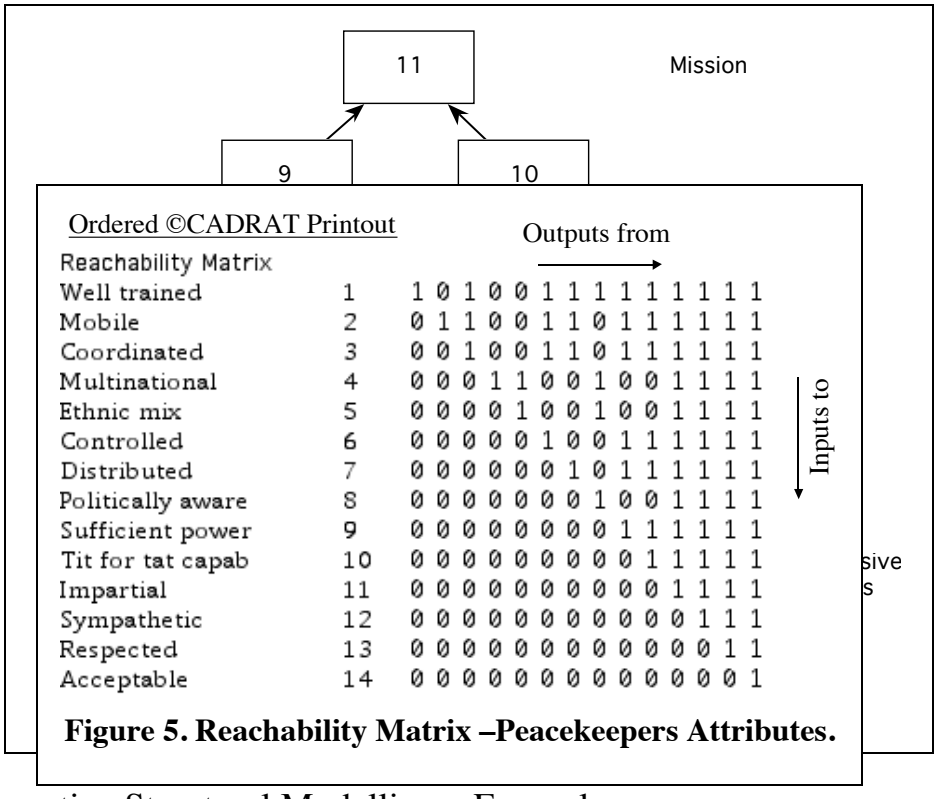


Figure 5. Reachability Matrix –Peacekeepers Attributes.

Interpretive Structural Modelling—Example

Given a set of factors, representing almost anything, their mutual structure may be determined in several ways. Simply by asking the question "Does Factor A contribute to

Factor B, or is it the other way round?" we may develop matrices of Contribution. Sometimes, the structure is obvious, often it is far too complex for us to see without help.

Consider the attributes of an ideal Peacekeeping Force:

• Sufficient power • Impartial • Distributed • Respected • Sympathetic • Acceptable • Mobile • Tit-for-tat capable • Multinational • Ethnic mixed • Co-ordinated • Controlled • Politically sensitive • Well trained

How might we relate these attributes? By asking the *asymmetric* question—

"*Does Attribute A strongly contribute to Attribute B, or vice versa?*"

The resulting Reachability matrix is shown in Figure 5. Note that all the other attributes contribute to "Acceptable", which therefore goes to the top of the attribute enhancement tree. "Well trained", on the other hand, contributes to most other things (excluding "Mobile", "Multinational" and "Ethnic Mix") and therefore goes to the bottom of the tree. Other attributes fit in between these two extremes using the logic captured in the matrix.

The resultant tree is shown in Figure 6. ISM has grouped the data and identified sets within the data. The example is simple, to illustrate the technique. The method is powerful, however, and it works very well for complex issues, too.

Stakeholder Analysis *with* ISM

Stakeholder Analysis

Perhaps the most difficult part of Stakeholder analysis is identifying the stakeholders. It seems all too easy to identify beneficiaries and overlook losers. The definition of stakeholders in any issue is as follows:

> *"those who have something to gain or, **particularly**, lose in / from a given situation or issue"*

Stakeholders are often those who "own" Issue Containing Systems.

Once identified, the analysis goes as follows:

- Establish individual *objectives* of each

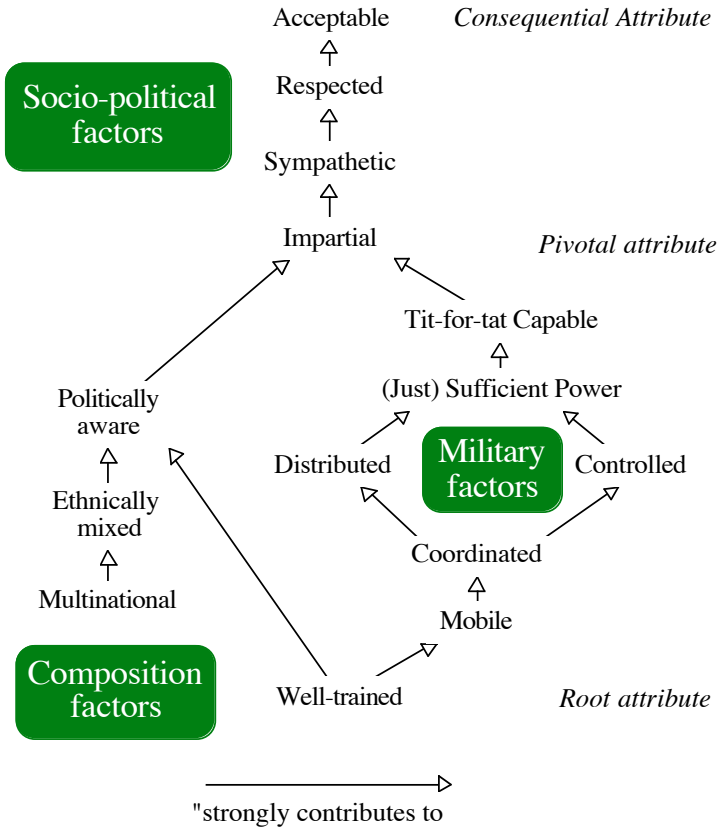


Figure 6. Peacekeepers' Attribute Enhancement Tree

stakeholder:

  - ideally, by asking them in a forum promoting honesty
  - alternatively, by rôle play—inferior, often the only option, however

- Identify relationships between objectives of all stakeholders:—
  - use Interpretive Structural Modelling (ISM follows) or similar
- Hence pinpoint bases for synergy/dysfunction between all stakeholders

Consider the following example:

Issue—a new, "rationalized" railway timetable has been introduced and is causing concern.

Stakeholders	**Objectives**
train company business	fewer, fuller trains, greater profit
train drivers & guards	more trains, more pay
station staff	more trains, job security, satisfied passengers
train maintainers	reliable trains
signalling and rail staff	fewer trains, robust system, trains on time, less track maintenance
passengers	less crowded trains, frequent trains, more leisure trains

Putting the Objectives Together

Figure 7 shows the reachability matrix resulting from the pair-wise comparison of objectives. In this case, the question posed was "does Objective A *help to achieve* Objective B, or is it the other way around, or do they not relate?" This question is less rigorous than for the attribute enhancement structure, which was "does attribute A *strongly contribute to*…" The most rigorous question which could be posed in this context is "does A *cause* B?" Exclusive causality is difficult to establish, however, and to use this expression would result in very few relationships being identified.

Reachability Matrix														
Robust systems	1	1	1	1	1	0	1	1	1	1	1	1	1	1
Reliable trains	2	0	1	1	0	0	1	1	1	1	1	1	1	1
More trains	3	0	0	1	0	0	1	0	1	0	1	1	1	1
Less track maint.	4	0	0	0	1	0	0	0	0	1	0	1	1	1
Fewer trains	5	0	0	0	0	1	0	1	0	0	0	1	0	1
Frequent	6	0	0	0	0	0	1	0	0	0	1	1	1	1
Fuller trains	7	0	0	0	0	0	0	1	0	0	0	1	0	1
More leisure	8	0	0	0	0	0	0	0	1	0	0	0	1	0
Trains on time	9	0	0	0	0	0	0	0	0	1	0	0	1	0
Less crowded	10	0	0	0	0	0	0	0	0	0	1	0	1	0
Greater profit	11	0	0	0	0	0	0	0	0	0	0	1	0	1
Satis. passengers	12	0	0	0	0	0	0	0	0	0	0	0	1	0
More pay	13	0	0	0	0	0	0	0	0	0	0	0	0	1
Job security	14	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 7. Railway Reachability Matrix

The matrix shows that Job security is at the top of the Intent Structure, while Robust Systems is at the bottom. The liberal scattering of '0's in the upper right half suggests that the structure is quite rich. Figure 8 shows the resulting structure.

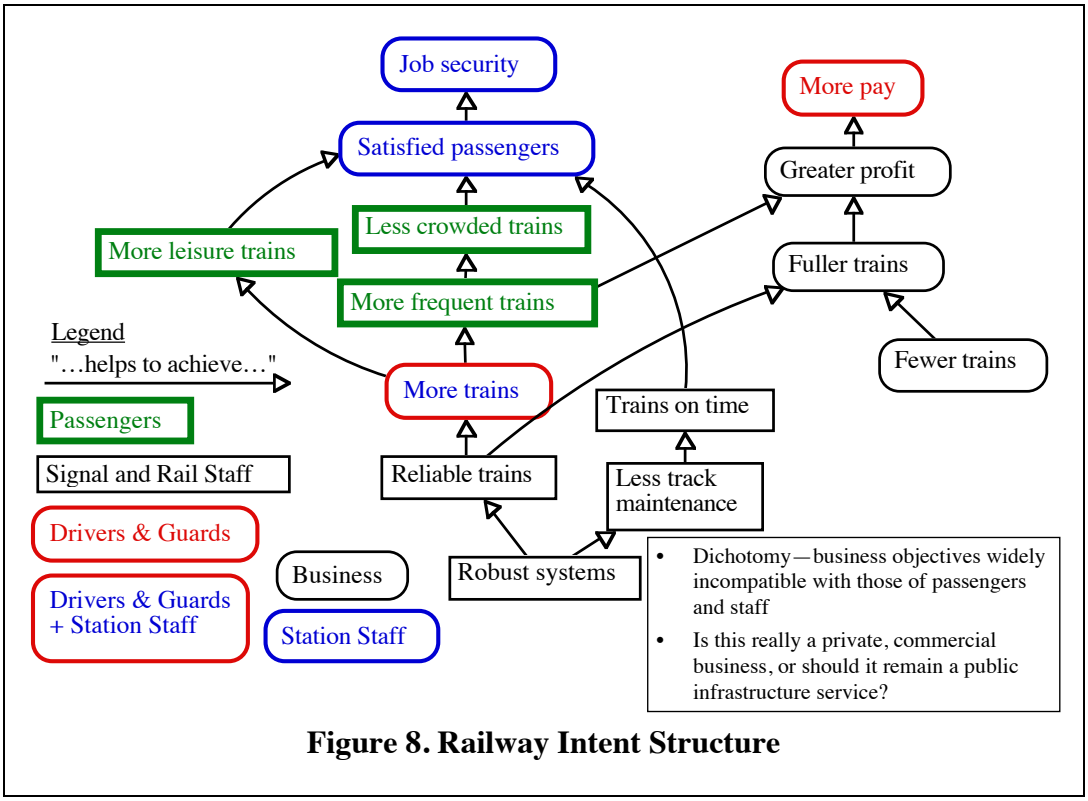


Figure 8. Railway Intent Structure

From the Intent Structure, it is evident that there is some dichotomy. The interests of the railways as businesses are at odds with the interests of passengers and railway station staff.

Notice how, using stakeholder analysis with ISM, enables the exploration of so-called "soft issues", widely regarded as intractable. The analysis does not solve/resolve/dissolve the issue, but it does identify the core aspects and the essential differences between viewpoints. In this example, the Intent Structure shows who "owns" each objective, and it is helpful to see how different people "line up." Ideas for improving the situation are almost inescapably driven simply by examining the Intent Structure.

TRIAD Building System

The TRIAD Building Systems is a powerful means of generating process models and system architectures which is lean and focused, and which incorporates risk management

The TRIAD

The TRIAD is a set of three components which, together, act as a nucleus for generating strategies, actions, processes, functions and architectures.

Figure 9 shows the archetypal TRIAD. A Prime Directive is recognized. Threats to achieving that Prime Directive are identified, and Strategies are conceived both to achieve the Prime Directive and, at the same time, to overcome or neutralize the Threats.

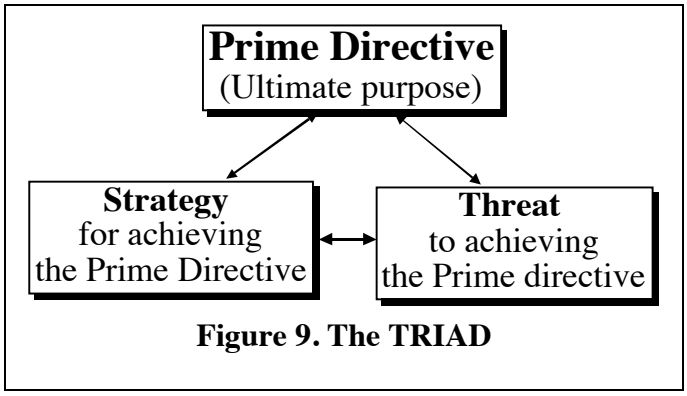


Figure 9. The TRIAD

The Concept of a Prime Directive

The Prime Directive is a statement of the ultimate purpose of an entity or system. It pervades all aspects of the system's development, evolution, performance, behaviour, effectiveness, eventual senility and demise.

The Prime Directive of Homo sapiens sapiens is generally taken as:

"*To propagate the species*"

…which requires

- procreation,
- nurturing, and
- social development of following generation such that they can continue the process.

Our human Prime Directive (PD) drives our social behaviour, our instincts, and even our human form. However, the Prime Directive, "To Propagate the species", is shared by every living organism on the planet, so it is a poor discriminator. More precise PDs are needed.

Prime Directives - Examples

1. For the UK Air Defence System:-
"To neutralize enemy air incursions into UK air space"

2.For a University:-
"To advance understanding"

3. For a family:-
"To nurture offspring"

4. For a government:-
"To improve the nation's well-being"

The Prime Directive may seem bare: that is intentional, to clarify ultimate purpose.

Semantic analysis is used later to draw out the full richness of the PD's meaning.

Given a Prime Directive, therefore, it is useful to analyse it semantically, to extract precise meaning. Consider the following:

Semantic Analysis of the UK Air Defence Region's Prime Directive

"*To neutralize...*	"To eliminate the threat from....
....enemy.. .	.....those declared by government to be hostile who....
...air incursions.. .	... enter by air without permission.....
..into the UK ADR".	.....into the designated airspace legally defined and internationally promulgated as sovereign UK airspace"

Implied Means:- Use of U.K. Air Defence assets

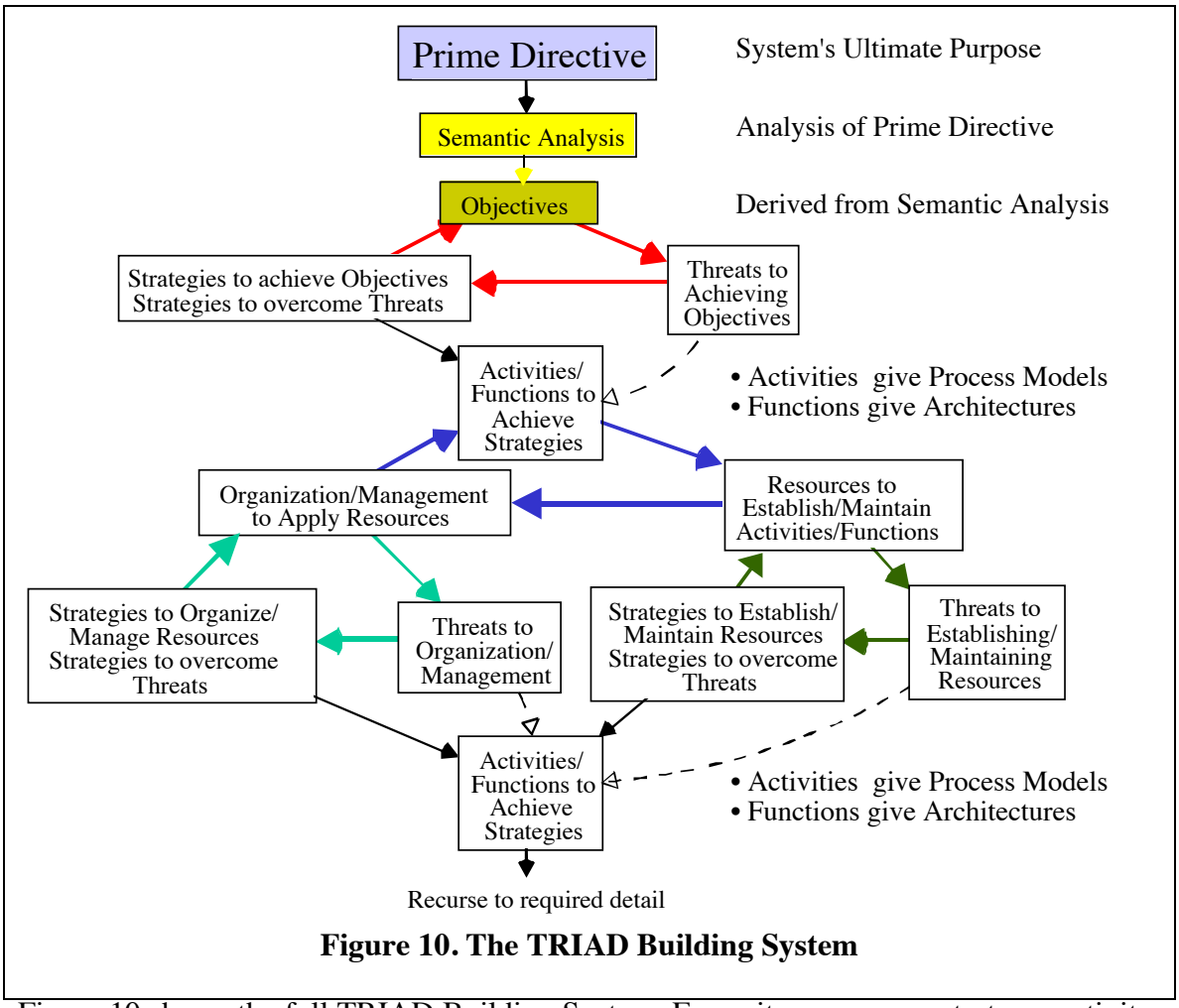


Figure 10. The TRIAD Building System

Figure 10 shows the full TRIAD Building System. Every item, process, strategy, activity, etc. is generated directly to achieving the Prime Directive. That is why the approach results in such lean, focused solutions. The method also recognizes and seeks to neutralize threats. Expertise may be needed in identifying and predicting threats in particular domains.

As the figure illustrates, The TRIAD Building System generates both Process Models and Architectures. Following sections show how these are achieved respectively.

Generating Process Models from the TRIAD Building System

Process Model Exercise

Mission:— To Introduce an En-route radar into the interior of a large Far East Nation

Objectives:—

- Generated using Stakeholder Analysis

Threats to each objective:—

- Generated by domain experts

Strategies to address each objective, overcome respective Threats:—

1. Research subject *before* selecting aim; seek advice about the politics, economics and culture surrounding the situation; appreciate the motivation of the recipient, his viewpoint and aspirations…

2. Etc., etc.

OBJECTIVES (SAMPLES)	THREATS (SAMPLES)	STRATEGIES
(Customer) Improved mobile force deployment	Radar System not part of effective overall flow control system.	Assist customer/user by helping to design overall system
(Own) Repeat Order Business	Perceived lack of Quality by Customer/User	Provide first-class after-sales service and improvement programme
	Incompatibility	Develop compatibility not only with existing and planned equipments, but also with operating and support methods and practices
	Customer does not like Britain and British ways	Employ in-country agents; train all relevant staff in the language and culture of the country; encourage customer/user visits to supplier organization; support in-country social activities

The strategies are formed into a precedence network using Interpretive Structural Modelling. (Ideally, activities needed to achieve each strategy should be generated and then the whole should be sequenced. This is because some strategies are ongoing and their activities may be spread out in time, deferred and/or repeated. However, for the sake of simplicity in this example, strategies have been sequenced directly.)

The resultant Precedence Network is shown at the top of Figure 11. Drawn down from the network is an activity network, and beneath that is a resource chart, showing different resources and their amounts. At the bottom, the human resources have been organized into Phase Teams. The whole is a coherent Process Model.

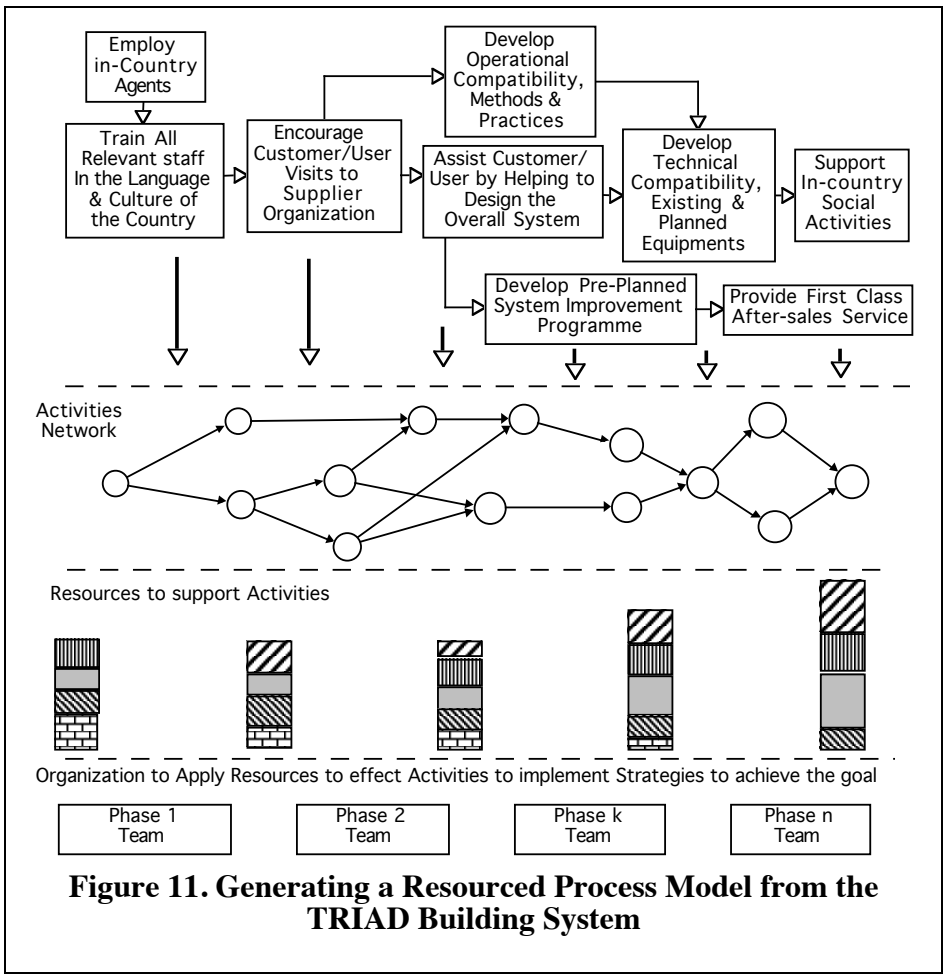


Figure 11. Generating a Resourced Process Model from the TRIAD Building System

Generating Architecture from the TRIAD Building System

Far Side of the Moon

- As part of a design project for a Base on the far side of the Moon, a series of threats was identified to the Base and to the associated Long Base Interferometer Array
- The project is called Lunar Deep Space Centre (LDSC)

TRIAD at Work

Figure 12 and Figure 13 show the first two columns of a table used to generate functions in response to perceived threats. (The numbers in the headings refer to steps in a

procedure, the Seven-Step Continuum, which drives all the way from symptoms to fully designed system solutions).

Step 2/3. Threats to Achieving the PD	Step 2/2. Strategies to Overcome those Threats
Meteorites and cosmic rays	Build underground by drilling sideways from inside crater rims. Use basalt rock as protection and in place of domes or bubbles to retain atmosphere
Poor Communications with Mission Ground Control	Deploy a Moon satellite communication system that always has dual sight of both Earth transmitter-receivers and LDSC
Lack of trained and willing personnel	Establish a continual training programme and select only the fittest personnel, psychologically and physically. Pay very well!
Inadequate resources at LDSC	Provide LDSC with systems to create/mine/manufacture resources, rather than the resources themselves, e.g. smelters, machine tools, borers, tunnelers, etc.
Personnel unable to cope with environment in LDSC	Select only psychologically screened personnel. Provide a varied environment within the LDSC, with different "themes" in different parts of the complex. Mix the sexes.

Figure 12 Generating Strategies—A

Inadequate Deep Space Astronomy	Use a large crater as a dish. Steer beams electronically, to facilitate time sharing and optimal utilization. Ensure radio communications with Mission Ground Control does not interfere. Install best quality data/image extractors as close to dish as possible. Harden above ground elements.
LDSC operating expense	Use solar power. Use lunar resources for power generation, mineral resources, insulation materials, etc. Minimize the management overhead.
LDSC construction expense	Build into lunar surface, rather than create "bubbles" on the surface. Construct from lunar materials where practicable.
Inadequate medical facilities for returning missions and LDSC staff	Provide comprehensive medical facilities with compression chambers, artificial gravity machines, psychological state inducement drugs, etc.

Figure 13 Generating Strategies—B

Conceive SOI Functions and Activities

Figure 14 and Figure 15 are further extracts from the table. In this case, the first column is a repeat of the right hand column in the tables above. At the right are functions, or functional units, which would undertake the strategy.

Strategies to Overcome Threats	LDSC Functions to achieve Strategies
Build underground by drilling sideways from inside crater rims. Use basalt rock as protection and in place of domes or bubbles to retain atmosphere	Construction
Deploy a Moon satellite communication system that always has dual sight of both Earth transmitter - receivers and LDSC	Satellite communications management
Establish a continual training programme and select only the fittest personnel, psychologically and physically. Pay very well!	Earth-based training LDSC continuation training
Provide LDSC with systems to create/mine/manufacture resources, rather than the resources themselves, e.g. smelters, machine tools, borers, tunnelers, etc.	Small-scale mining, smelting, refining, working and manufacture from raw materials

Figure 14. From Strategies to Functions needed by the LDSC to Implement those Strategies—A

Select only psychologically screened personnel. Provide a varied environment within the LDSC, with different "themes" in different parts of the complex. Mix the sexes.	Psychological profiling and monitoring
Use a large crater as a dish. Steer beams electronically, to facilitate time sharing and optimal utilization. Ensure radio communications with Mission Ground Control does not interfere. Install best quality data/image extractors as close to dish as possible. Harden above ground elements.	Dish construction Electronic beam control Data extraction Image processing
Use solar power. Use lunar resources for power generation, mineral resources, insulation materials, etc. Minimize the management overhead.	Solar power generation
Build into lunar surface, rather than create "bubbles" on the surface. Construct from lunar materials where practicable.	Construction Development of local materials
Provide comprehensive medical facilities with compression chambers, artificial gravity machines, psychological state inducement drugs, etc.	Perform medical checks Manage astronaut rehabilitation/acclimatization

Figure 15 From Strategies to Functions needed by the LDSC to Implement those Strategies—B

Astronomical communi - cations	Satellite communi - cations	Radio com - munications	Training (Earth based)	Training (On the Job)
Materials	Medical	Psychological management	Image pro- cessing	Astronomy control
Solar power generation and storage	Astronaut re- habilitation	Contingency planning and resource management (CPRM)	Operations	Astronomical laboratories
LDSC Management	Central Warning and Controls (CW & C)	Inspectorate	Administrate - ion	Maintenance
Earth re - supply	Personnel/ human re - sources	General stores Astronomy stores	Infrastructure —sewerage, waste dis- posal, com- munications, message handling, etc.	Atmospheric conditioning — heating, cooling, ventilation, purification, humidity, etc.
Power distri - bution				

Figure 16. Rationalized Set of LDSC Functions

Figure 16 Accumulates the various functions generated by the TRIAD Building System and rationalizes the list

Identify SOI Intra-flows & Cluster

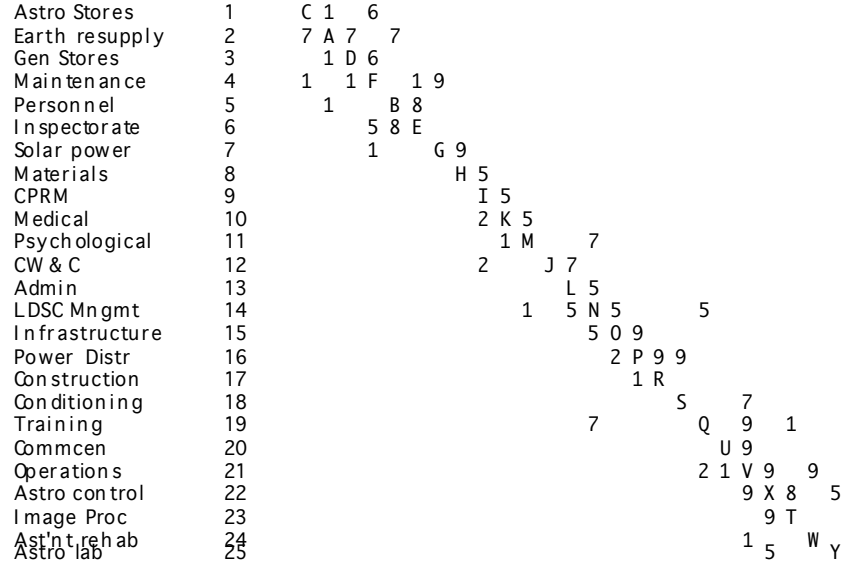


Figure 17. LDSC Functional Interactions and Relationships—Clustered N^2 Chart

Figure 17 shows the functions plotted into an N^2 chart. In this instance, the numbers in the N^2 chart have been chosen to represent the perceived "strength" of association between the various elements

Functional Sub-systems and Intra-flows

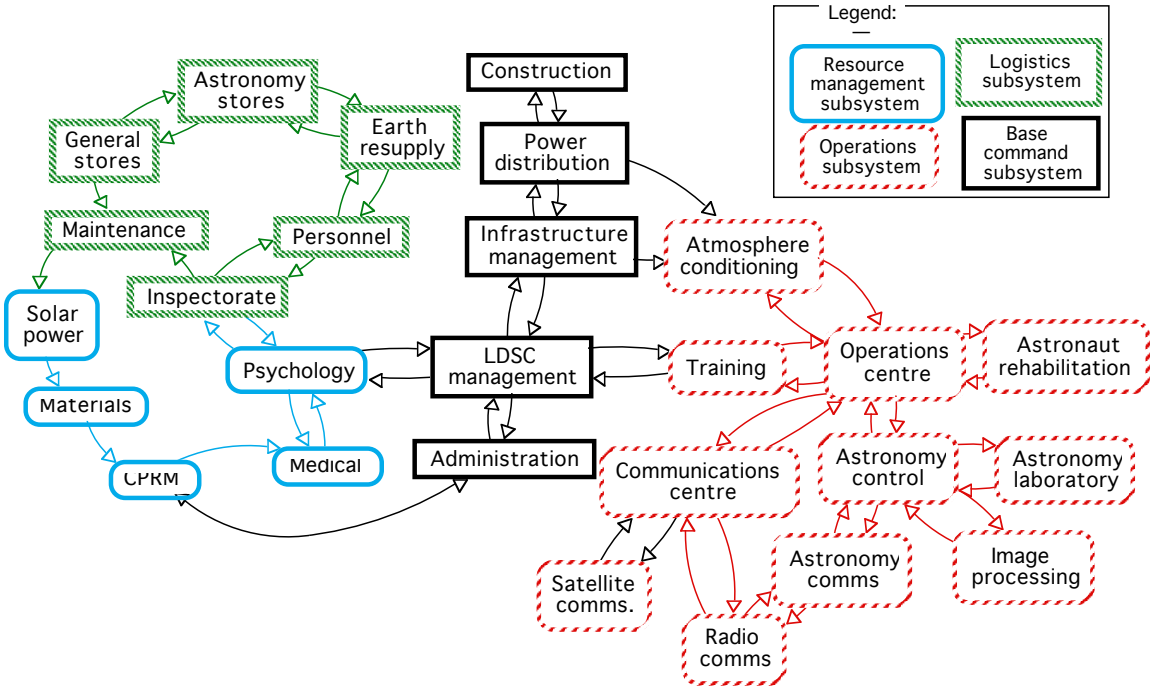


Figure 18. Functional Architecture Direct from Clustered N^2 Chart

Figure 18 shows the N^2 chart as a more familiar organizational diagram. The 4 distinct groups formed when the N^2 chart was clustered.

Sibling Inter-flows

Figure 19 shows the four groups as containing systems i.e. the representation has undergone a hierarchy shift, concealing some of the detail. The Containing Systems at this higher level of hierarchy are connected—as always—to other Containing Systems Some of these are supportive, some natural and threatening.

One resource, potentially, is water at the Moon's poles—although that may take time and considerable expense to realize.

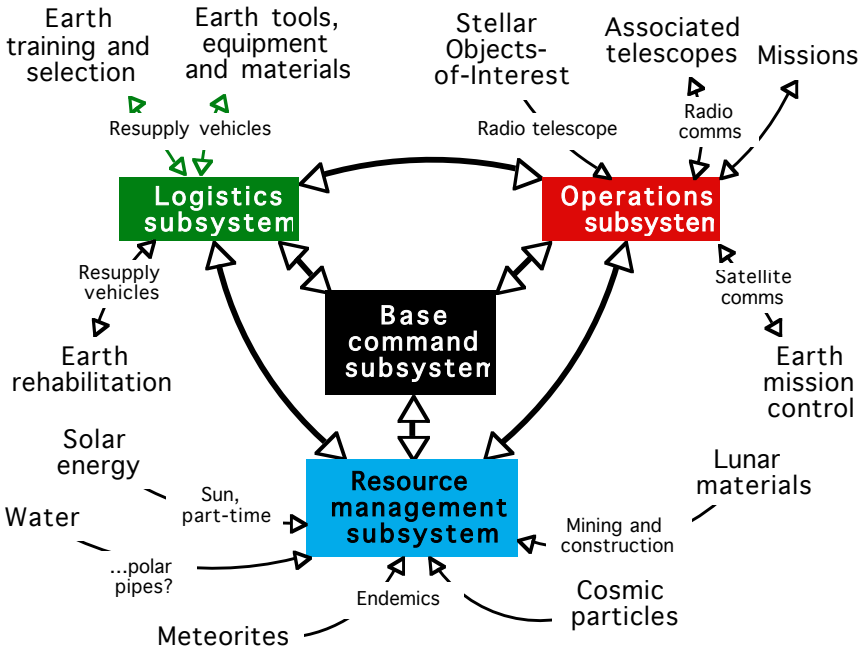


Figure 19. Hierarchy Shift: Containing Systems and Sibling Inter-flows

TRIAD Building System—Summary

The TRIAD Building System is straightforward, yet it produces sound results very quickly—when driven by domain experts, who know both what is to be achieved and the likely threats to its achievement. By itself, the TRIAD Building System produces an unordered list

Conclusion

This brief paper has introduced several useful problem-solving techniques, which may be used alone or together according to task. There are many more such techniques, and many more methods composed of different arrangements of techniques.

With any method, it takes time and practice to become familiar. Problem solving is not a rote, "handle-turning" activity. It requires thought and care. After all, the context-free techniques introduced in this paper contain no information—all of that is supplied exclusively by the users. The old adage applies: garbage in, garbage out.

In practice, all such methods are best deployed by a team, which becomes familiar with the methods over a period of time. Team performance improves rapidly at first, but in the end the best results come from smart people with the best knowledge of the subject.