The Systems Engineering Tool Box

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"Give us the tools and we will do the job"

Winston Churchill

Matrix Diagram (MD)

What is it and what does it do?

A Matrix Diagram (MD) is a tool that allows a team to identify the presence and strengths of relationships between two or more lists of items. It provides a compact way of representing many-to-many relationships of varying strengths. An example matrix diagram is shown in figure 1.

		List 2				
		Item A	Item B	Item C	Item D	Item E
List 1	Item 1	⊙	⊙		△	
	Item 2					
	Item 3			○	△	
	Item 4		○	△		
	Item 5	△		△		○
	Item 6		○		⊙	

Figure 1: An Example Matrix Diagram

Figure 1 shows, by the symbols, the presence of a relationship between the items in list 1 and the items in list 2. The different symbols indicate the strength of the relationship and an empty cell indicates no relationship.

The contents of the lists being related in a matrix diagram can be:

- Data
- Information
- Functions

- Concepts
- Actions
- People
- Materials
- Equipment
- Etc

However, the contents of the lists should have something in common so that they represent a set of "something".

Why do it?

Relationships between things are often complex (many-to-many) and require us to think in more than one-dimension. The Matrix Diagram is a simple tool that allows relatively complex situations to be analysed in a simple straightforward way. They help us to expose interactions and dependencies between things that help us to understand complex causal relationships.

Where and when to use it?

A Matrix Diagram can be used where we wish to identify and assess the strength of relationships between to or more lists of items. It is particularly useful for examining the relationships between:

- a set of vague and un-measurable items with a set of precise and measurable items (such as relating customer requirements to technical requirements).
- two sets of items that are physically different (such as design solutions to a set of technical requirements)

There are five basic types of Matrix Diagrams that allow for different numbers of lists to be to be explored. The Types are:

- L-type
- T-type
- Y-type
- X-type
- C-type
- QFD Type (Quality Function Deployment)

L-type Matrix Diagram

The L-type is the basic Matrix Diagram that allows the relationships between two lists. It is shown schematically in Figure 2.

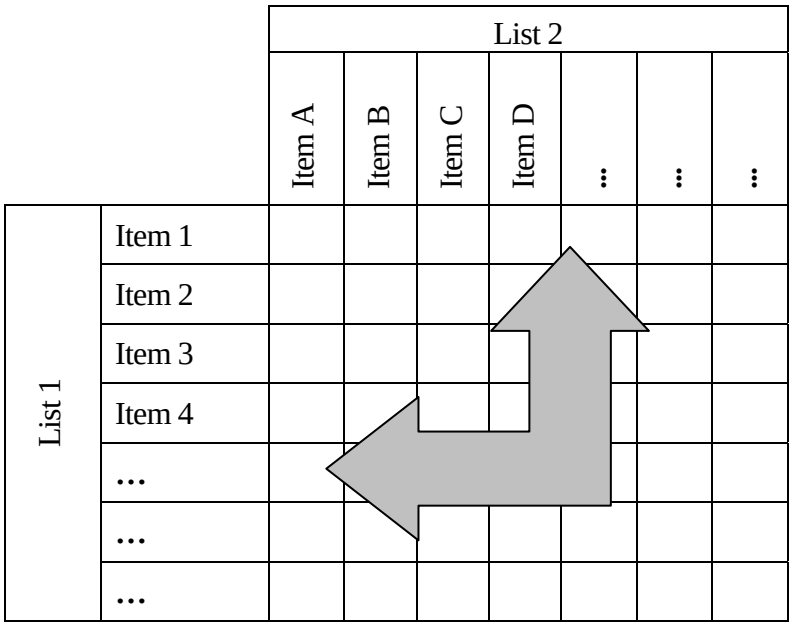

Figure 2: The L-type Matrix Diagram

T-type Matrix Diagram

The T-type is effectively two L-types joined by a single list. It allows one list to be related to two others and is shown in Figure 3.

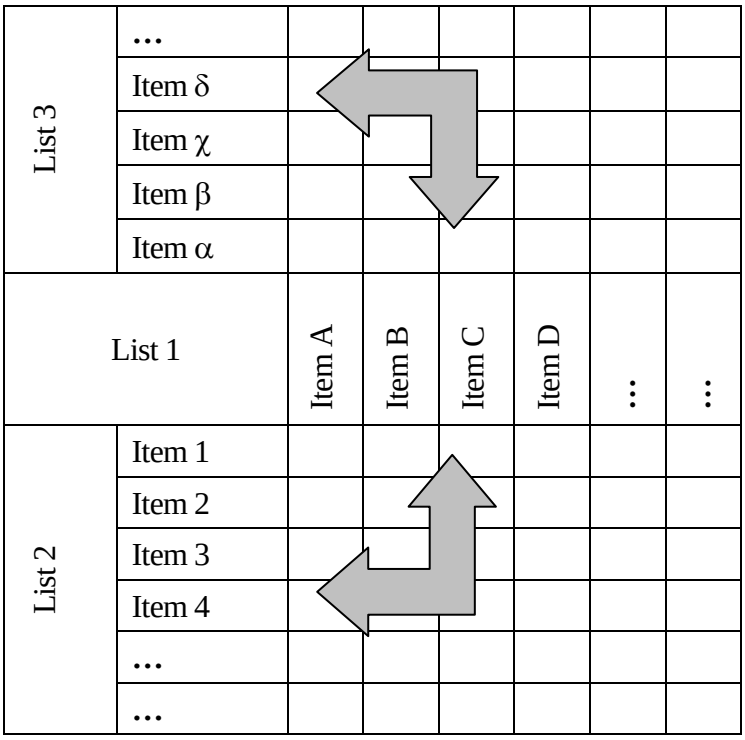

Figure 3: The T-type Matrix Diagram

Y-type Matrix Diagram

The Y-type Matrix is combination of three L-type matrices as shown in figure 4

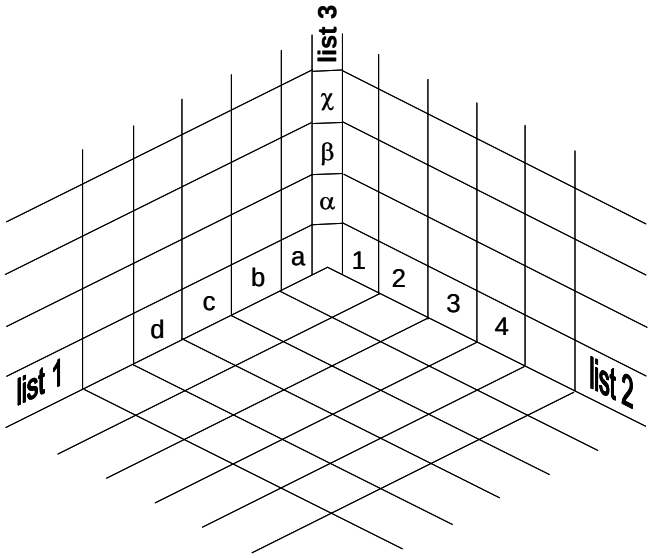

Figure 4: The Y-type Matrix Diagram

X-type Matrix Diagram

The X-type Matrix is combination of four L-type matrices as shown in figure 5

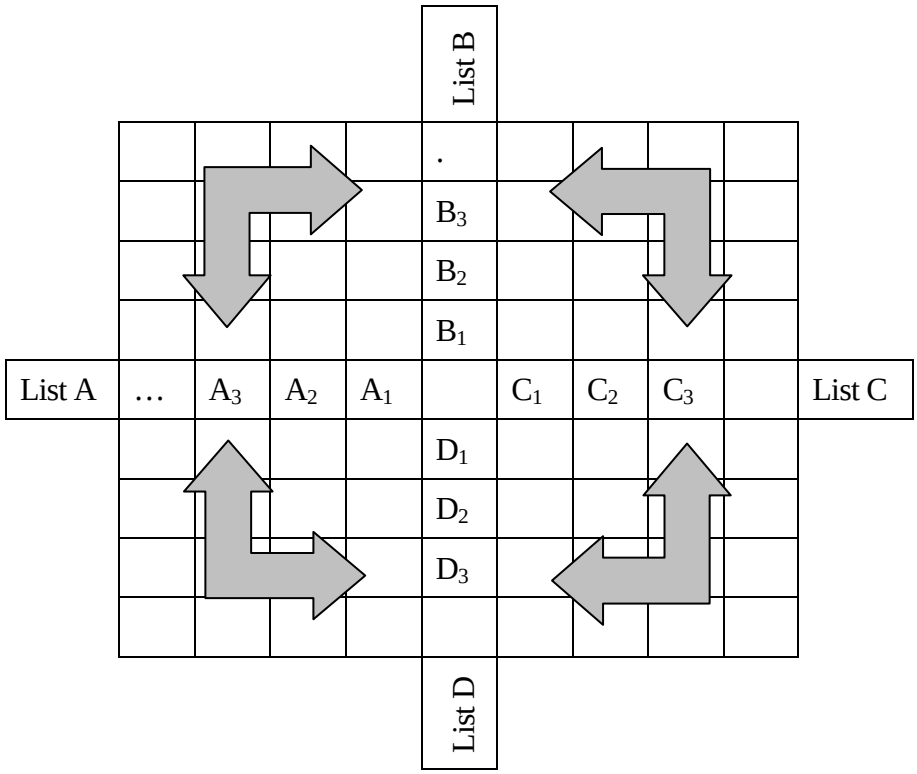

Figure 5: The X-type Matrix Diagram

C-type Matrix Diagram

The C-type Matrix Diagram is a represented as a cube whose sides are three lists as shown in Figure 6. This diagram allows for three dimensional relationships. However, this can be difficult to visualise even with the cubic arrangement and it is often easier to interpret by using the "inside" of the cube as shown in figure 7.

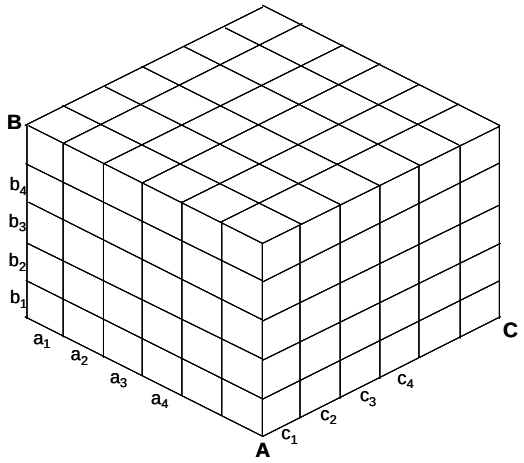

Figure 6: External C-type Matrix Diagram

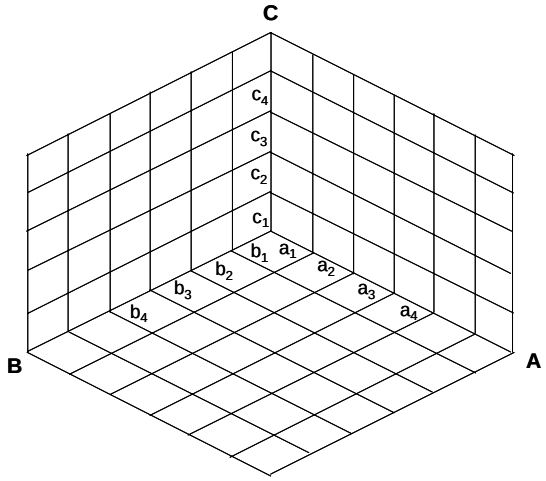

Figure 7: Internal C-type Matrix Diagram

Quality Function Deployment (QFD) Type Matrix Diagram

One derivative of the Matrix Diagram that has become widespread is the Quality Function Deployment Chart. This in its simplest form is simply an L-type Matrix Diagram with an ancillary list that has a many-to-one relationship with one of the main lists. It is used to investigate the relationships between sets of requirements that are developed during new system (product) introduction. While several organizations use QFD as the foundation for their New Product Introduction Process (NPIP), many only use its first iteration to examine the relationships between customer requirements and technical requirements. QFD

in all its varieties is describe as a separate tool, but as an example Figure 8 shows a QFD phase 1 chart.

Intelligent Washing Machine				IWM Functions and Features																	
				Wash Sensing		Load Machine			Manage Water			Clean Items			Manage		User I/O			
				Detect Load Make Up	Measure H20 Hardness	Load Dirty Items	Unload Clean Items	Load Cleaning Agents	Fill Water	Drain Water	Heat Water	Wash	Rinse	Dry Contents	Select Cycle	Control Cycle	Receive user inpu	Display user messages	Suuport	Interface to Services
Customer Requirements	Intelligent Washing Machine	Good Wash	Good Dry Performance	⦿		△				○	⦿		○			○	△			
			Good Wash Performance	⦿	○	△		○	△	△		⦿	○		⦿	○	△			○
		Ease of Use	Automation & Intelligence	⦿	○			○	△						⦿	△				
			Easy to use Controls	△													⦿	⦿		
			Access Ergonomics			⦿	⦿	⦿			△									
		Cost	Purchase	⦿	△	△	△	△	△	△	△	○	△		○	⦿	⦿	⦿		△
			Running		△			○	△			△			⦿	△				⦿
		Long	Reliable	○	△				△	△	⦿	○	△		△		△	△		
			Easy to Maintain	△	△						○		△							
		Style	Attractive			△	△	△									○	○		
How Much				White-Black +full colour	+/- 1%	5kg miminum	5kg minimum	all currently available	15l/min cold 10-28C	10l/min+/- 1l	equivalebt to 1600rpm spin	Reflectance of 500	removal of cleaning to ...	Moisture content of	no damage to clothing	All standard Cycle as	All Cycle info	All Cycle info	Refer to CS 123	Stabdard BS fittings

Figure 8: Example QFD Phase 1 Chart

This chart is an L-type matrix modified as shown in figure 9.

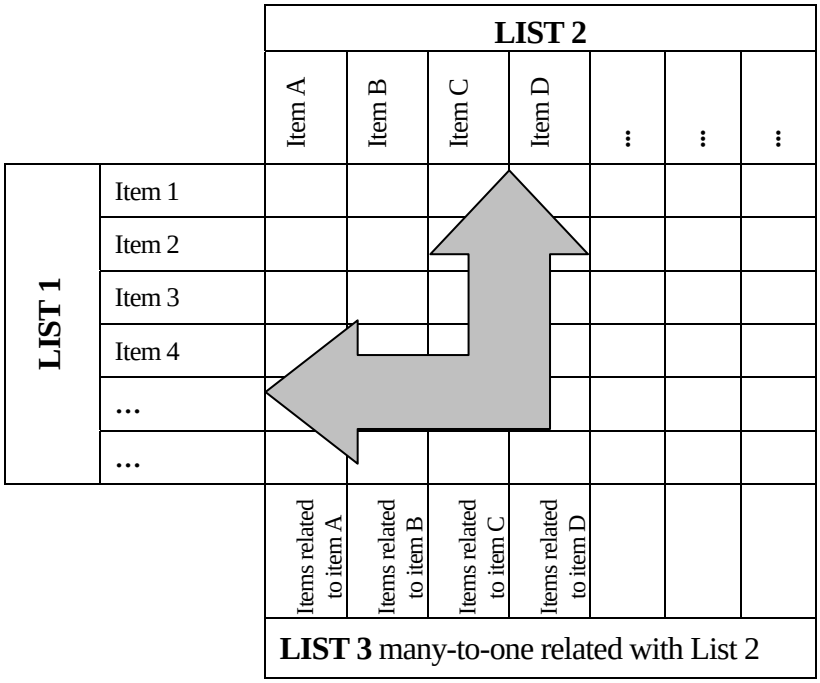

Figure 9: The Basic Structure of the QFD Type Matrix Diagram

In the first phase of QFD, List 1 comprises customer requirements which are often expressed in vague and ambiguous terms. List 2 comprises the set measurable technical requirements for the system

under development. The matrix is therefore used to show the relationships between the customer and technical requirements. Blank or sparse rows or columns will highlight potential deficiencies in either set of requirements. List 3 is used to set target levels for the measurable technical requirements in list 2.

Who does it?

Constructing a Matrix Diagram is best performed by a team to draw upon the experience and expertise in that team. It is important to emphasise that the quality of the outcome is dependent upon the team and hence team selection is critical. What is important is expertise in both lists. As an example, consider the phase 1 QFD briefly described above. List 1 comprises the customer requirements gathered in many organizations by the Marketing Function. List 2 comprises the technical requirements of the system under development generated by Systems Engineers. Its obvious that both groups need to be present to generate a good chart.

Time size is also an important consideration and the recommendation is for 5 to 8 members. Below 5 and there is perhaps not enough critical mass to represent all the stakeholders adequately. Above 8 creates management issues which often leads to bureaucracy and consequent slowing of progress.

There is great benefit in terms of quality of output and time efficiency if the Matrix Diagram sessions are facilitated by a Matrix Diagram craftsman. This is particularly important for virgin teams.

How to do it?

The process for constructing a Matrix Diagram is given in figure 10.

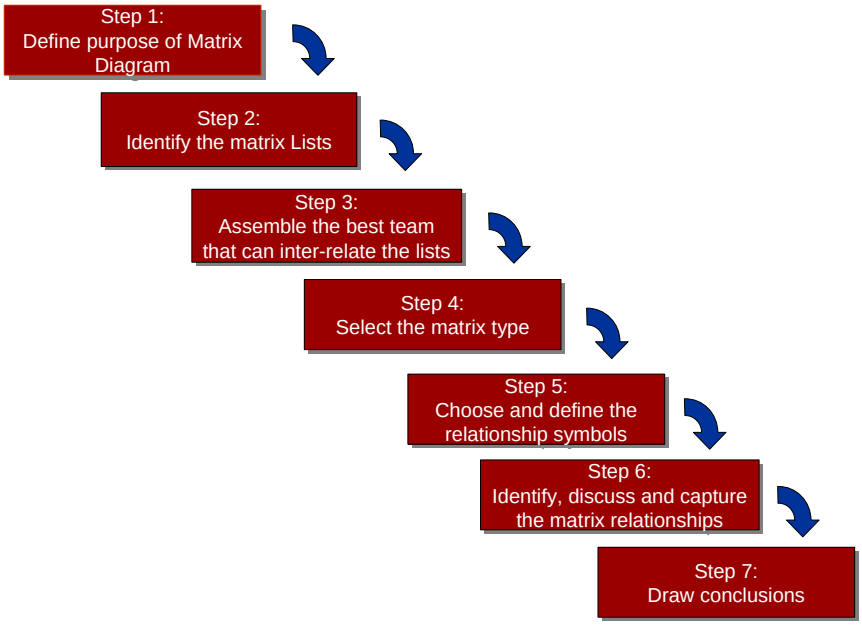

Figure 10: The Process for Constructing a Matrix Diagram

STEP 1: Define purpose of Matrix Diagram

Clarity is important here. Not we should use this tool to explore situations but rather if that is the case we should say so clearly.

STEP 2: Identify the matrix lists

This should follow automatically from the purpose. What is often problematic here is whether the lists:

- exist
- are sufficiently complete
- are representative and unbiased

If they do not exist then effort may have to be expended to generate them and it is a question of whether this is done by the same team that will determine the relationships. As a general rule, it is recommended that the list originators take part in the determination of relationships simply because they understand their respective lists. On the other hand it is import to recognise the potential for bias. A classic example of this is asking a bunch of Engineers to help generate a set of customer requirements by pretending to be customers. The outcome is very plausible but probably not representative of the true customers needs and leading to the wrong conclusions being drawn.

It is important here to realise that the lists should contain items that have something in common so that they represent a set of "something". This again is easier to say than do. In some situations it is easy. For example if you were investigating train lateness against train operator and type of service it would be hard to get the contents of the lists mixed up. But, what about lists of customer requirements and technical requirements? Some customer requirements are technical requirements so in which list do they reside?[1]

STEP 3: Assemble the best team that can inter-relate the lists

This step is obvious linked with step 2 and can in fact happen before the completion of step 2. Whatever the formation of the team it must contain the expertise and experience to be able to inter-relate the lists.

STEP 4: Select the matrix type

If the earlier steps have been completed this should be straightforward, although for any particular situation you may wish to construct more than one type of Matrix Diagram.

[1] This particular issue is discussed and resolved in the QFD tool description.

STEP 5: Choose and define the relationship symbols

The relationship symbols accomplish two tasks:

- indicate the presence of a relationship
- indicate the strength of a relationship

In some instances only the presence of a relationship is sought, in which case any symbol will do. However, in most case both presence and strength is sought and two common ways exist for capturing this:

Symbolic method

◉ Strong relationship
○ Medium relationship
△ Weak relationship
No relationship

Numeric Method

9 Strong relationship
3 Medium relationship
1 Weak relationship
0 No relationship

The two are equivalent and can be interchanged – but the numeric method can lead to unnecessary and potentially dangerous "tinkering". In general, people are much more willing to accept the strong, medium and weak symbology and not question its efficacy. However, when faced with the numeric method people often wish to change the relative values (i.e. medium = 4.5) or attempt to introduce inter-range values (i.e. use the complete scale from 1 to 9). While in principle this is not a problem, in practice it leads to endless debate, constant recalibration and criticism of the tool (the classic case of a poor workman blaming his tools). My experience is to start with the symbols and if a numeric scale is required translate to this after using the symbols.

There is a third option that attempts to capture whether the relationships are positive or negative. This uses

9 Strong positive relationship
3 Medium positive relationship
1 Weak positive relationship
0 No relationship
-1 Weak negative relationship
-3 Medium negative relationship
-9 Strong negative relationship

While this can be useful, it is difficult to apply when a relationship can be either positive or negative. In my experience of this scheme the disadvantages outweigh the advantages. The best approach is to indicate that there is a relationship on the Matrix Diagram and make notes about the type and form of the relationship.

STEP 6: Identify, discuss and capture the matrix relationships

This step is the core of the tool. It is best to be disciplined and systematic in how the cells of the matrix are examined for potential relationships. Whether to proceed row-wise or column-wise depends largely on the situation under considering. As a general rule row-wise is often the most appropriate since we tend to place the "most important" list vertically on the left (for the L, YC and QFD type matrices this is the dominant position).

Each relationship should be considered in turn and the presence and strength debated until the team reaches a consensus. Since the symbols are measures of the relative strength it can be useful to start by quickly scanning a row (or column) to identify the strongest relationship which can be assigned with the appropriate symbol. This performs a type of calibration against which the other symbols and agreed. You may also find that having completed a row (or column) that you may need to go back and change some of your symbols.

Deciding on symbols will (and should) provoke discussion and it is important to record some of this. While I would not necessarily recommend making notes for every symbol entered on a Matrix Diagram, it is certainly worthwhile recording those discussions where there was lengthy or frank debate (i.e. an argument). This is extremely valuable if you ever have to return to a diagram at a later date, or for other people who will use the diagram but were not present during its construction.

STEP 7: Draw Conclusions

There should be a purpose for undertaking a Matrix Diagram and once it is complete it should reviewed against that purpose to draw out conclusions. It is worthwhile capturing these on the diagram for future reference and to inform others.

What Goes Wrong: The limitations of Matrix Diagrams

Ambiguous, invalidated, and incomplete lists. It is important to think through what is in each list and what constitutes membership of a particular list.

Attempting to precisely quantity the strength of a relationship. Matrix Diagrams are useful tools in exploring a large number of

items quickly to reduce the scope of a situation down to the vital few. As such the broad strong, medium and weak relationships are ideal. Attempting to be precise can be damaging to the team and the value of the tool.

Wrong expertise and insufficient experience in teams. Like a great many Systems Engineering tools, the Matrix Diagram tool is really only a vehicle to help extract the knowledge and experience from the team. The wrong team can still follow the process and arrive at a result – but that resultant Matrix Diagram will be of little use.

Success Criteria

The following list represents a set of criteria that have been found to be useful when using Matrix Diagrams.

- Team size between 5 and 8
- Team constitution has expertise and experience in the lists being related
- Use an experience independent facilitator
- Plan for one half-days effort. Irrespective of the situation a Matrix Diagram will take about ½ day to construct.
- Define clearly what we are trying to do
- Find some mechanism for validating the lists
- Use the symbols and convert the numbers later
- Record reason final symbol decision in contentious situations