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Identification and resolution of induced complexity in PSS enterprises

Michael J de C Henshaw, Maged S Morcos, Carys E Siemieniuch, and Murray A Sinclair
Engineering Systems of Systems Group, Loughborough University, UK.

Abstract

There is currently a trend towards a Product Service Systems (PSS) business model for complex products and many traditional manufacturing organisations are undergoing a transformation to PSS. Generally, this will lead to greater dependency between certain organizations within the multi-organization enterprise and this in turn induces complexity. The Role Matrix Technique (RMT) has been applied as a decision support tool for organizational transformation and this paper shows its usefulness within an enterprise context and, more particularly through a case study, in the PSS context. The agglomeration of a number of case studies is presented to show how the RMT characterises types of industry and, through this, the focus case study of PSS transformation in the transport sector is shown to include both manufacturing and service structure, which leads to considerable induced complexity.

The paper concludes by showing how the RMT is a useful decision support technique for managers engaged in enterprise transformation and, for the specific case study considered, shows how complexity may be induced during the PSS transformation.

Keywords

PSS transformation, decision support, induced/intrinsic complexity, Role Matrix Technique

Introduction

The significant decline in manufacturing as a percentage of GDP in most developed economies since the 1970s and the corresponding increase in service business has led to many product companies moving into services whereby organisations have moved from producing a product to the provision of through-life service support for the products within systems and systems of systems. This represents a significant transformation across the company and Young (2008) has drawn a contrast between those companies for which this has been a strategic imperative, leading to increased market share, with those that have drifted into services and failed as a consequence of unpreparedness. For the manufacturers of highly complex products a transformation to a business based on Product Service System (PSS) has appeared attractive and this more recent development brings with it additional challenges associated with the enterprise nature of the transformation that is necessary (Purchase, et. al., 2011). For example traditional engineering processes, tools and methods are considered effective at managing product development. However, the ever-increasing requirements for improved quality and performance on the products being developed (i.e. continuous evolution of technologies supporting even more integration and interoperability, greater functionality, improved reliability and adaptability) and the new demands placed on industry to develop logistic and operational support strategies as part of their products, creates even more complex and extensive supply systems which, in turn, require new strategies for organisation design and operations. Evidence from participants in PSS enterprises (Johnstone & Dainty, 2008; 2009) indicates that there is significant interdependency between the various contributing organisations along often extended supply chains and that significant complexity arises as a result of the transformation process. Based on observations of transformation examples that inspired the research reported herein, there appears to be an unnecessary increase in organisational complexity that is brought about by the cultural heritage of a manufacturing organisation maintaining a lasting organisational imprint upon the emerging service business.

In this paper, we demonstrate the application of an enterprise mapping technique, called the Role Matrix Technique (RMT) (Callan, et. al., 2006; Siemieniuch & Sinclair, 1999; 2000, 2002) through which the roles involved in a particular activity and the relationships (boundaries, interactions, responsibilities and accountabilities) between them are represented in such a way that managers may visualise and understand them and thence reduce the complexity of the allocation of roles in a service enterprise. The technique has been successfully applied in a series of case studies within single

organisations in the past, but this research shows its benefit within the context of a multi-organisation enterprise system.

To be clear: we consider an enterprise system to comprise multiple organisations contributing to shared goals that cannot be achieved by any of the organisations individually. In general, for the cases considered here, the customer organisation is also part of the enterprise system. It is also important to distinguish between the intrinsic complexity of the enterprise system, which is due to the inherent complexity of the products and supporting activities, and the induced complexity that arises as an enterprise organises itself as a response to the perceived intrinsic complexity of the products to be developed (Sinclair, 2007; Read, 2008). Induced complexity could be described conversationally as an over-complication of the organisational structures; such complicatedness, in itself, causes conceptual complexities in terms of understanding how to manage the organisation.

The RMT can provide a representation of both the 'as is' and 'to be' organisation associated with a particular set of activities that the enterprise conducts. This acts as a decision support system to enable creative managers to identify bottlenecks, role-conflicts, information blockages and other complications which they can use as a basis to identify alternative structures (the 'to-be' organisation) that better meet the purposes of the enterprise within the activity under consideration.

The perspective that we take is that a prime organisation, responsible overall for providing a product-service mix, is a part of a wider enterprise system, within which the component multiple organisations contribute to the service activity under consideration. The customer is also a part of the enterprise and participates in the creation of value (Ng, et. al., 2008).

We begin with an overview of the RMT; we consider the manner in which information is collected in order to construct the matrix and demonstrate the power of the technique in which interactive development of the model with participants of the enterprise leads to important insights among those participants. Next, we describe the nature of organisational complexity and illustrate this through a case study. This study concerns a major transport manufacturing company in the throes of transformation from product-based business to a PSS and focuses on an activity concerned with ensuring fleet availability and reliability to a train operating company. The 'as is' structure exposed by the RMT appears to be a hybrid of a typical manufacturing structure with a service structure superimposed upon it. This is a highly complex organisational structure. We conclude with an interpretation of the case study results to indicate the appropriate considerations for organisational development to better meet the PSS challenge.

The Role Matrix Technique (RMT)

The RMT was developed by Siemieniuch & Sinclair (2002) and forms part of a suite of linked methods that relate organisational structure to organisational strategy, culture, and performance (Hubbard, Siemieniuch, & Sinclair, 2010). It is essentially a qualitative approach in which key stakeholders provide their view of the organisational structure (ie who is responsible for doing what and when) associated with a particular activity. Numerical values may be derived from the mapping, as in the case study below, but these are intended as a guide to aid participant understanding, rather than to provide definitive quantification.

The RMT is relatively quick and straightforward to use, but its benefit relies on the participation of enterprise system stakeholders (e.g. in a workshop). It promotes discussion about the set of roles required for the activity under consideration and thence leads to a clearer definition of the roles and the relationships between them. It should also be noted that a 'role' can be allocated to a single human, a group or team of humans or an intelligent software agent. Furthermore any one of the above could hold a single role or a combination of roles.

A fundamental premise of the technique is that once an organisation has grown to the stage where differentiated roles are considered necessary, and later in its growth where differentiated functions appear, the different role-holders will have different conceptions of the organisation. While there will be much overlap among these conceptions, some of the differences will not be apparent, and will cause friction in what is intended to be a smoothly-operating organisation. This same reasoning applies even more so for organisations bound by contract into an enterprise. It is this that contributes to the induced complexity both within the organisation and between organisations, and which the RMT can expose as problems to be addressed by the stakeholders.

Figure 1 shows a role matrix grid; the vertical dimension is the degree of responsibility in planning, resourcing and scheduling operations to achieve targets (i.e. freedom to set goals) divided vertically into the four levels of none, low, medium and high. The horizontal dimension is the degree of discretion in achieving the target and executing operations (i.e. flexibility to achieve goals) divided into the three levels of low, medium and high. The matrix, then, has twelve boxes, as shown in Figure 1, with the 1st box being the uppermost one where the controller of the activity normally resides while the 12th box is the least one where most executors, subcontractors or un-skilled labour are normally located. A generic interpretation for each of the four extremes is provided in the figure.

Figure 1: Role Matrix Grid, Source: (Callan, Siemieniuch, & Sinclair, 2006)

Figure 2: Role Analysis Representation (Role Activity Diagram)

Starting from a specified activity, each role that contributes to an activity is defined in terms of its responsibilities. It is important to note that this is a definition of the role, not of individuals/agents/groups who might wholly or partially execute the role. The roles are arranged in a Role Activity diagram (Figure 2) that contains four classes defined as follows:

- Controlling role: this is the role responsible for the performance of the activity. In general, there should only be one role in this box.
- Execution role: this role carries out the work of the activity; it will often be the subject of delegation from a higher role.
- Constraining role: this role provides advice that is very unlikely to be ignored. The significance of the advice will generally derive from the hierarchical level of the constraining role, or from authority vested in the role (e.g. health and safety).

- Discretionary role: this role provides advice that can be ignored; for instance, it could be peer based advice that derives from past experience, but does not necessarily have any authority attached to it.

Each role is represented with a particular symbol in the role analysis diagram (Figure 2), and these are then mapped to all the activities that make up the overarching process (Figure 3). There are rules for aggregating the roles from lower level processes to the higher level, which largely concern the relative importance of the four classes of roles described above: Controlling Role (most important), Constraining Role followed by Discretionary Roles and then by the Execution role.

Figure 3: Allocation of roles to complete process

A further set of rules are applied to transfer the roles to the Role Matrix Grid (i.e. Figure 1); correctly positioned according to the dimensions and then linked to other roles with one of four possible relationships. The relationships are

- Delegation, with an arrow from delegator to delegate
- Constraining advice, with an arrow from the adviser
- Discretionary advice, with an arrow from the advisor
- Hand-over, which represents the situation where one role completes a portion of a task and ‘hands-over’ the work item for completion (or continuation) by another role. This does not involve delegation or matters of authority and should, therefore, occur only within one box of the Role Matrix. The arrow indicates the direction of hand-over and could be double-headed.

In general, the researcher will carry out an initial analysis of roles in the activity to provide some baseline definitions; however, the organisational learning is generated during the workshop in which managers collectively consider the roles and relationships. This provides an opportunity to clarify the roles within an activity and to understand the relationships from the perspective of ‘as is’ and to potentially identify a better ‘to be.’ The types of changes that might be identified are splitting or combining of roles, shedding of superfluous roles, changes to the relationships between roles to better reflect the objectives of the activity. This is done using the role analysis diagrams (Figure 2) and then transferring the new configurations to the Role Matrix Grid.

Blobology

Based on the experience of mapping activities in different industrial sectors, Siemieniuch (2009) has noted some general characteristics of the clustering (blobs) that appear when the roles are mapped to the Role Matrix Grid. These are summarised in Figure 4. Of course, it is not a definitive

requirement that particular industries comply with a particular shape, but it does provide an insight into the likely prevailing culture and modus operandi of the organisation under study. In most cases, the blobs have an intuitive logic in terms of the type of decision making and authorities that typify the particular industry in question. Comparison of the clustering of a particular case with the typical plots in Figure 4 will cause the researcher and managers of the organisation under consideration to question the reasons for departures from the typical in-sector shape, thereby enhancing understanding to the prevailing organisational characteristics.

Figure 4: Blobology of the RMT

Organisational complexity

PSS is generally a suitable approach for creating a sustainable business around complex products. There is, therefore, a high degree of intrinsic complexity in the engineered systems and the organisations associated with design and manufacture of the types of products that are suitable for management through PSS. As the intrinsic complexity increases, so an induced complexity is introduced (Sinclair, 2007; Read, 2008) that is very often manifested in complex organisational structures. It should be noted that induced complexity is not necessarily an undesirable characteristic, because it is necessary that a controlling system must have an appropriate level of complexity to manage the system it aims to control, as implied by Ashby's law of requisite variety (Ashby, 1962). Nevertheless, there is a tendency for organisations to become over-complicated (i.e. unnecessarily complex) when faced with the delivery of a complex product or service. One may speculate that the transformation from product-based to PSS organisation of itself increases the intrinsic complexity of the system. Gerstner (2002) has stated that service businesses are much more difficult to manage than product businesses. There are many factors that lead to this conclusion, especially those associated with culture, but increased complexity is certainly a contributor. In PSS there are multiple cultures that contribute to the increase in conceptual complexity, and the more complicated organisational structure will also contribute to an increase in complexity. A specific example of increasing organisational complexity is that which arises between the front and back offices that occurs in the transformation from product-based to PSS (Morcos and Henshaw, 2009; Purchase et. al., 2011). It is therefore imperative in such a transformation to avoid the induction of unnecessary complexity. The case study reported below reveals significant organisational complexity at the enterprise level, much of which is induced through the process of transformation.

Case Study - Global Transportation Manufacturer (GTM)

PSS is characterised by a shift in the product development process from an organisation trying to sell as many products as possible, to developing products and services that meet the client's specific needs. PSS is a credible and attainable approach to creating a sustainable business based around products of a sufficiently complex nature. The subject of this case study is a Global Transportation Manufacturer (referred to throughout as GTM) moving rapidly towards a PSS business. The case study concerns a particular activity carried out by GTM, entitled 'ensuring fleet availability and reliability', which goes to the very heart of PSS operations.

GTM is considered to be one of the Industry-Leading Transportation Manufacturers; it is present in more than 60 countries and has approximately 70,000 employees worldwide about half of which design, manufacture, sell and support a wide range of products in the rail sector. The focus of this study is the UK division of GTM.

Service Support Contract

The service contract in GTM is organised in the following manner (Figure 5a): The Train Operating Company (TOC) expresses its requirement for new trains. This is likely to be significantly influenced by the Department for Transport (DfT) which oversees letting of TOC franchises and has a major say in the creation of new fleets in the UK. ROSCO (a leasing financial services body) finances the deal and places an order with GTM Design Business to design and build the trains. GTM Services Business bids separately for a maintenance contract. Once all necessary quality and client requirements have been checked, delivery is made to TOC. GTM Services Business is responsible for any after sale and delivery services and activities. During the development of the Role Matrix for this study it was noted that the contracting relationships had been recently altered (Figure 5b); this is discussed further below.

Figure 5: GTM Service Support Contract and Relationships. DfT refers to the Government Dept for Transport, TOC to Train Operating Company and ROSCO to the leasing company (and client for GTM).

Role Analysis and Construction of the Role Matrix

‘Ensure fleet availability and reliability’ is a major activity within the overall GTM service process; it is discharged through provision of the appropriate level of maintenance activities to meet demanding delivery times and cost constraints. The activity was modelled with six sub-activities, into which the various roles were placed. These sub activities were then conflated to provide the top level view for the activity shown in Figure 6.

The ‘as is’ Role Matrix was developed through a workshop. The participants included the Fleet Director, Business Process Improvement Manager, Director of Integrated Asset Management and a Services Research Engineer. In all, twenty-nine different roles were identified for the main activity; these are listed in Table 1 with an acronym for easy reference in the subsequent figures.

Through workshop discussion, the roles were allocated to the four quadrants of the Role Activity Diagram as shown in Figure 6. The roles were then distributed onto the Role Matrix grid and the relationships identified by considering each role in turn. This is presented in Figure 7a-e.

Acronym	Definition	Acronym	Definition
PjM	Project Manager	SS	Store Staff
FD	Fleet Director	SSS	Supplier sales Staff
ROS	ROSCO – Leasing Company and Client	SL	Shift Leader
TOC	Train Operating Company (Client)	WOGN	Work Order Generator
PPM	Project Performance Manager	Maint	Maintenance Team
MM	Materials Manager	QHSE	Quality, Health, Safety and Environment
EM	Engineering Manager	FC	Financial controller
PM	Planning Manager	DA	Design Authority
DM	Depot Manager	BPI	Business Process Improvement
TM	Team Leader	HRP	Human Resource Partner
MB	Material Buyer	ConfM	Configuration Manager
MF	Material Forecaster	MO	Methods Operator
MC	Maintenance Controller	Mcom	Materials Controller

SSM	Supplier Sale Manager	FAM	Facilities Manager
		Lorm	Line of route manager

Table 1: Roles, with Acronyms, for ‘Ensure Fleet Availability and Reliability’ Activity

Figure 6: Role Activity Diagram for ‘Ensure Fleet Availability and Reliability’ Activity

Figure 7a: Role Matrix Grid plotted for ‘Ensure Fleet Availability and Reliability’ Activity

Figure 7b: Delegation Relationships

Figure 7c: Constraining Advice Relationships

Figure 7d: Discretionary Advice Relationships

Figure 7e: All Relationships (note that there are no hand-over relationships in this case)

Analysis

The following observations inform the analysis of this activity:

- There are 76 relationships between the 29 roles, but only 25% are delegation, the remaining 75% relationships being either constraining (40%) or discretionary (35%) advice. There are no hand-over relationships.
- There are three main roles: Project Manager (PjM), Engineering Manager (EM), and Depot Manager (DM) that are highly loaded with significant levels of interaction with the Fleet Director (FD), Business Process Improvement Manager (BPI) and the Train Operating Company (TOC) and ROSCO through delegation and constraining/discretionary advice. This set of constraining advice is summarised in Table 2. The high levels of constraining advice, in particular from TOC and ROSCO, suggests that these roles must resolve input and potentially conflicting needs of the major stakeholders.

Role	Constraining advice from
PjM	BPI, FC, QHSE, EM
EM	QHSE, TOC, DA, ROSCO
DM	TOC, BPI, FC, FAM

Table 2: summary of constraining advice on Project Manager, Engineering Manager, and Depot

- As noted above (see Figure 5b), the contracting arrangements had been changed shortly before the data collection for the case study so that advice from ROSCO would reach GTM via TOC, and not

directly (Figure 5b). This was a specific action to reduce the risk of conflicting advice that would arise through separate communications. ROSCO is primarily concerned with the preservation of asset value (i.e. eventually they will wish to sell on the rolling stock), and so their advice mainly concerns maintenance requirements that sustain that value. The TOC has requirements related to the operational aspects of providing the train service. Thus any conflicts in advice between TOC and ROSCO are now resolved between those organizations and a consolidated advice is passed to GTM.

- The constraining advice from TOC and ROSCO on PjM restricts the choices available to this role when making decisions and adds a time-critical dimension. This potentially leads to delay in the delivery process, and the safety responsibility of the TOC means that the advice provided may make delays unavoidable.
- The blobology (extracted from Figure 7e) of the activity appears to include two shapes: the diagonal is associated with the direct maintenance operation and a vertical blob is associated with the supporting functions (such as materials management etc.), see Figure 8.

Figure 8: Blobology of 'Ensuring Fleet Availability and Reliability' Activity in GTM

The primary maintenance roles conform to the diagonal structure, which is similar to the traditional manufacturing organisation structure. This implies that those charged with the direct execution of maintenance work have little freedom to plan or set goals. However, the main customer facing roles conform to the vertical structure, implying that those in contact with the customer at all levels have medium flexibility in the choice of the approach to achieving the goals. The 'as is' organisation, therefore, reflects an interesting hybrid of service structure and hard manufacturing/engineering structures. This is probably appropriate to the nature of the business, but it is not clear whether this structure reflects a stage in the organisation's transformation or a general structure applicable to PSS. The RMT does not provide a specific analysis of the reason for a particular structure. Similarly, although the RMT does identify the interactions between these manufacturing and service structures, it does not specifically define the interface. A more detailed specification of the interface could be achieved through other techniques (e.g. interviews) but the RMT can be used to identify areas on which to focus in a more detailed analysis.

The high level of advice compared to delegation in the structure suggests that the operation is subject to considerable constraint. However, the constraining advice from external organisations tends to be directed at single roles within GTM, which will relieve the risk of confusion (although suggesting the need for careful consideration of the characteristics of the people who are to fulfil the role). Nevertheless, the role matrix suggests that within GTM there should be opportunities to streamline the flow of information. An important aspect of the discretionary advice is that the majority of the flow is up the organisation; i.e. this represents feedback from lower levels of the organisation hierarchy to the management. GTM has a deliberate policy of encouraging feedback and this represents a good practice in terms of the service organisation.

The feedback to the Design part of the organisation is almost negligible. Although constraining advice flows from the Design Authority to the Engineering Manager, there does not appear to be a

mechanism for learning and information to flow back from the service (maintenance) organisation to the Design teams. Essentially, the design and service organisations operate independently. This may reflect the level of maturity of GTM in the transformation to a PSS organisation and should be an area for future development. It has been observed in previous applied research, albeit unreported, that automotive assembly lines have the same mistakes in design which tend to persist from one line to the next because of poor feedback from maintenance.

The change in the contracting arrangements, shown in Figure 5, is considered to provide a good example of efforts within the enterprise to reduce induced complexity that was created at the time of the initial transition to PSS trading. Essentially this reduces the number of advice interactions. A next step might be to consider the extent to which induced complexity within GTM itself can be reduced through similar action.

An informal assessment of the role matrix technique was conducted as part of the workshop with managers. During construction of the role matrix, the managers remarked on the complexity of the organisation, but also observed that there is probably even greater complexity for individuals who must balance the demands of many different activities, and not just the one under direct consideration in this case study; remember that this case study focuses only on one major activity within the overall business. Nevertheless, they remarked on the benefit of being able to ‘sit back’ and visualise the organisation in such an exercise. As researchers, we would observe that as with many enterprise visualisation methods it is not so much the finished article that provides value, but the process of generating it that provides new knowledge and insight to the managers responsible for the activity under consideration.

Although the case study was conducted with the management of only one organisation in the PSS enterprise, the activity being studied required consideration of the roles of several organisations and the relationships that existed across the enterprise. Until now, the RMT has been applied mostly within organisations; only two studies have considered activities across several organisations: the case study above and an unpublished study of UK MoD acquisition. It is suggested that the RMT may be of particular value for activities conducted by enterprise systems, because the roles and relationships across the enterprise system will often be less well understood by individual managers than those directly under their purview. Thus a collaborative RMT exercise incorporating managers across the enterprise system will be a means of identifying and, hence, reducing induced complexity during enterprise transformation. The PSS transformation currently taking place in a great many areas of complex product manufacture appears to exemplify this problem situation.

Conclusion

The Role Matrix Technique has been applied over a number of years as an analysis aid for managers faced by the need to transform their organizations. These accumulated studies have indicated that the structure (“blobology”) of the resulting matrix tends to characterize particular types of organization, generally along the lines of industrial sector. It is, of course, noted that the RMT is applied to activities performed within an organization and the characteristic blob relates to that particular activity and may not be typical of the organization as a whole. The technique is essentially qualitative and should be thought of as a decision aid to managers, not as a prediction or prescription technique. The study reported in this paper demonstrates the potential usefulness of this technique to inform enterprise transformation and it will be of particular value in the identification of unnecessary induced complexity during the process of transformation. The changes necessary to reduce such complexity must be identified through management innovation or other organisational modelling tools; however RMT may be used to explore possible solutions.

We also draw some conclusions with respect to the PSS transformation. Application of RMT to GTM has enabled the identification of some PSS specific features, namely the complex constraints that arise within the enterprise, the need for specific actions to ensure feedback from the maintenance engineers to senior managers and thence to other parts of the enterprise, and the hybrid nature of the structure between ‘product’ and ‘service support’. It is not clear at this stage whether this is hybrid structure is typical or even desirable and this will require further investigation. PSS is generally

regarded as a good strategy for complex products, but it does appear that the transformation from product-based to PSS organisation generates additional induced complexity and future studies should focus on the methods and interventions that reduce the induction of unnecessary complexity.

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Appendix A – Rules for aggregation of roles within RMT

The rules for aggregating roles and mapping them to the Role Matrix are illustrated in the diagram below (Figure A1). This is provided only as an example of how roles can be allocated.

Figure A1: Mapping roles to the Role Matrix

(A): DRC is the controlling role within the role analysis; hence DRC occupies position 1 in the Role Matrix. This position has the most responsibility and discretion for the activity in question.

(B)(C): both DD and CE provide constraining advice to the control role (DRC), hence they are positioned in the same cell of the Role Matrix; in this example this is cell 2, which indicates that DD and CE have a strong influence on achieving targets in this example, but the roles do not control the activity.

(D) (F): when positioning the executing roles within a process there must be an understanding of how the roles work within the process; thus there is a need for some interpretation and subjective judgements of the role interactions. For this example, all executing roles (LA, DRM, IPTL, A, DRS, IPT) have complete discretion about how the work is done, but IPTL, DRM, and LA roles (D) have more responsibility and are positioned in cell 4, whereas IPT, DRS, A (F) have less responsibility and are shown in cell 7.

(E): the IA role is only to provide discretionary advice and thus has little responsibility for the activity and also little influence on it. The role is allocated to cell 5 to reflect this moderate influence.