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DYNAMIC MODELLING OF RELATIONSHIPS IN COMPLEX SERVICE DESIGN SYSTEMS

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Abstract

Today's market conditions such as globalisation and digitalisation have made it challenging to design an effective service system that can efficiently balance organisational service capacity and customer service quality, hence ensure achieving business growth. One key reason might be related to the complex structure of relationships within and across functional disciplines that in often cases are dynamic and uncertain while occurring in multiple layers. Therefore, effective understanding of these interrelationships might be a significant step towards understanding the dynamics of a complex service system. In response to this challenge, this paper presents development and application of a systematic modelling and analysis framework that uses functionality of Change Prediction Method and System Dynamics to integrate multiple levels of relationships. The objective is to help decision makers understand key influencing factors and their underlying risk and impact on the system behaviour, i.e., customer experience, thus making organisation more adaptive in responding to changes and uncertainties. The ideas are illustrated through an expanded case study in British Telecom company.

Keywords: Service design, Complexity, Dependency modelling, Uncertainty, Telecommunication

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1 INTRODUCTION

Designing effective service systems has become critical to achieving business growth for any kind of product or service company, whether in pre-sale or after-sale service processes. Achieving the target is increasingly challenging in new markets: it requires dealing with multiple aspects of complexity that can come from functional disciplines such as technical system (e.g., operations), technological system (e.g., IT system), human resource, and marketing; in particular, in a condition that "everything is connected to and depended on everything else" (Sterman, 2001). This has made the performance of service delivery processes as an important competitive advantage.

From a managerial perspective, the context of Service Design System (SDS) is simply about making an effective compromise between organisational service capacity and customer service quality. However, the key to this objective is "multi-layered multi-domain relationship channels" that in often cases are dynamic and uncertain. In response to these interdisciplinary challenges, this paper presents the development of a multi-echelon modelling and analysis framework that can integrate micro and macro levels of relationships. The objective is to help decision makers understand key influencing factors and their impact on customer experiences, thus making the organisation more adaptive in responding to changes and uncertainties. The ideas are developed and illustrated through an expanded case study in collaboration with a British Telecom (BT) company.

In a telecom organisation, every single service process can act as a new process that delivers its unique service at the particular level of quality, and in many cases, certain processes can result in new products (Wynn et al., 2012). It might be due to such changes in company business strategy, availability of resources, investment in new technologies or even unforeseen happens such as weather conditions, and customer demand. For example, the strategy of cost reduction through the over-forecast planning of resources might lead to happy customers, but it would deploy more human resources in a safety net, and resulting in less efficiency (even if everything else goes well). On the contrary, the strategy of increasing revenue through the under-forecast planning of resources is very likely to make customers unhappy because of less accurate job allocation (more job allocation than expected), so resulting in less effectiveness. Therefore, the organisation should adopt a generic service planning systems that can consider the mutual impact between service stakeholders (such as organisation, employees, and customers) and business decision-making levels (strategic, operational).

This paper in concerned with a big challenge in complex business processes such as one in BT service system, to understand levels and dynamism of relationships and their impact on the system behaviour. It aims to help decision makers: understand appropriate level of granularity to model the relationships; generate useful scenarios to understand their impact, and understand low-risk improvement levers (e.g., cost-based, or time-based). Eventually, the managers might be able to draw low-risk service process on the experiments.

Hence, the complexity of designing service systems first discussed and multiple-facet nature of information relationships highlighted with particular attention on the *form of information*. To address the theoretical foundation, a recursive approach presented that combines functionality of Multiple Domain Matrix (MDM) (to map aspects of dynamism), Change Prediction Method (CPM) (to reflect the criticalities and underlying risks), and System Dynamics (SD) (to analyse behaviours at the system level) into an integrated framework. Efficiency of the proposed model then illustrated and validated using an example from the Telecom Company. Finally, the supplementary discussion provided a mean to figure out some improvement points of the model and to conclude the paper with some highlights.

2 COMPLEXITY LEVELS IN SERVICE DESIGN SYSTEMS

In the context of an SDS, complexity can stem from the complexity of multiple stakeholders involved in the process, including: *organisation* (that can be affected by government, market, environmental issues, and technological advancement), the *customer* (i.e., their expectations, behaviour, and culture), and the *channel* as the linkage mechanisms (contact person in Cook et al. 2002) between service provider and service receiver. It can be a kind of employee, engineer, website, call centre or a robot. For example, as far as related to the service organisation, the complexity of *organisational structure* can affect the relationships with stakeholders so far. For example, the emerging trends in technology (such as digitalisation) and market conditions (such as globalisation) have been made service provider and user

much closer than before, yet more complex to capture the multi-channel and multi-layered nature of relationships among them.
Accordingly, the vast literature existed to address the above issues, either in the case of development of a new service design (Menor, Tatikonda, and Sampson 2002; Smith, Fischbacher, and Wilson 2007) or improving an existing service design system (Hill et al. 2002; Seth, Deshmukh, and Vrat 2005). Further examples can be found in the reviews of Farrell et al. (2004), Hill et al. (2002), Roth and Menor (2003), and Seth, Deshmukh, and Vrat (2005).
In this paper, the premise is that stakeholders are the main source of complexity due to multiple levels of reciprocal relationships among them that can influence a service organisation at different levels. Therefore, should be made a distinction between organisational levels (strategic with long-term visions, tactical with medium-term missions, and operational with short-term tasks) and stakeholders (organisation, channels, customer), this paper debates that all organisational levels might not simultaneously affect (and be affected by) different stakeholders, and the degree of impact can depend on the mechanism of relationships among them.
Thus, we proposed a conceptual framework so-called Service Design Matrix (SDM) representing the associations between organisational levels in rows and stakeholders (organisation, employee, and customer) in columns. The presumption is that different stakeholders might have different preferences in defining key process elements, and these elements could be totally different in different time-scales of an SDS. The objective is to realise the most likely areas of an SDS in order to improve the tracking mechanism, so enabling the decision makers to act faster in responding to a change or mitigating its impact. The example of SDM for BT broadband service system is presented in Table 1.

Table 1. Service design matrix of the BT broadband service process

	Organisation-related	**Employee-related**	**Customer-related**
Long-term (invest for business growth)	Investment in delivery Stakeholder value Brand value Cash flow	Employee engagement Health indicators Human resource planning	Net Promotor Scope Churn rate Average revenue per user Up sell rate Market share
Medium-term (transform cost for efficiency)	Delivery of quality product Productivity Target setting	Training and development Health and safety Job satisfaction Contractors	Product performance Expected quality Use of other channels (e.g., BT.com)
Short-term (deliver superior experiences to customer)	Provision, repair, and overall work stack Lead-times Job completion Proactive to reactive jobs	Quality checks Resource availability Shrinkage and leave Sick leave Overtime jobs Loans	Right first time Early life failure, and repeat report Appointment kept Service experience (soft measures)

Another aspect of complexity in SDS is the degree of response to complexity. From the academic perspective, despite a vast literature, the majority of previous studies exploring service quality implicitly focused on the *quality* of relationships between stakeholders, rather than presenting the *mechanisms* to explicitly understand the criticality of relationships and their impacts on the business decisions. From the practitioners' point of view, the company has already adopted a variety of tools and techniques to figure out the sources of complexity, through compromising key performance indicators (KPIs). Therefore, they are essentially interested in drawing a big picture of customer satisfaction with respect to revenue/cost that can support decision makers at the strategic level.
Motivated by the literature gap and to respond the company needs, this paper highlights the integrated nature of relationships as the main challenge facing the modelling of relationships and discusses that:

- *Macro and Micro aspects of relationships can be considered together in the modelling*. For each level of granularity, a broad range of valuable models can be found in the literature, such as System Dynamics (SD) at the macro level (Van Ackere, Warren, and Larsen 1997; Bianchi 2010), and some matrix-based techniques at the micro level (Wang and Capretz 2009; Cai 2006). However, in reality, mature organisations use a combination of these tools to support dynamic decision making;
- *Data in the context of an SDS can be objective or subjective*. So it is more effective to consider both qualitative (Danaher and Mattsson, 1994) and quantitative (Yim et al., 2004) aspects of modelling relationships together. The proposed methodology in this paper would deploy the quantitative techniques in model configuration, and a qualitative framework for calibration;
- *The more aspects of the dynamism of relationships that consider in the modelling, the better understanding and more real representation of relationships can be achieved*. The idea is that multiple facets of relationships have some degree of information dependency. For example, relations at the time of creation of an activity would be more probabilistic, or relations between different levels of an organisation might be more functional rather than physical. Therefore, a better understanding of these facets can get more information on the essence of a relationship, resulting to effective modelling of them at a lower risk.

3 ASPECTS OF DYNAMISM IN MODELLING RELATIONSHIPS

Efficiently modelling of relationships is essential for effective decision making, i.e., the probabilistic relationship cannot result in a deterministic decision. However, there should be a distinction between different types of relationships according to their nature, structure, and impact. For example, dependency at the creation of an activity might be more problematic than the one at the modification time. The main contribution of this paper would be presenting an *integrated framework* that can simultaneously cover multiple aspects of relationships.

In doing so, and given particular attention to the *form of information*, we presented a set of eight-axis criteria to represent and analyse the relationships. The authors believe that each relevant reference in the literature can be somehow concerned with one or some of these criteria and that explicit understanding of these criteria can play a significant role in the explicit understanding of dynamism of relationships. They are briefly described in the following:

1. **Dimension**; in terms of dimension, relationship can be *two-dimensional* (direct relation between any two elements), or *n-dimensional* (that refers to both direct and indirect relationships between three or more elements);
2. **Time**; whether the relationship is existed for the first time in the process (dependency at *creation*), or is a kind of additional relation during rework (dependency at *modification*). The presumption is that information at modification steps are more mature, and so relationships can be more reliable;
3. **Nature**: as a provisional classification, relationships can be *physical* (or structural to confirm that the system is following the specifications) or *functional* (that aims to verify what should be done to satisfy objective functions). Physical relations usually refer to the process, while functional relations often come from the product or service requirements;
4. **Source**; a relationship can originate from an *internal* or *external* factor. There is no absolute way of classifying sources of relationships, but in the scope of this paper, it can stem from the customer requirements, organisation, or the employees (e.g., customer-engineer interactions during the installation of a broadband network);
5. **Quality**; based on the availability and reliability of information, a relationship can be *informational* (during which the quality and quantity of information might be improved), *hierarchical* (to exchange information between any two levels in the organisation, and whether in a top-down or bottom-up directions), or *sequential* (between any two element in the precedence network during which quality of information might be incrementally improved);
6. **Likelihood** determines the quality of existing a relationship. It can be *infrequent* (that might rarely happen), *frequent* (that happens in a regular manner), and *certain* (that happens for 100%). For example, completion of an allocated job might have a certain relation to the availability of people, but it has infrequent relation with a brand value of a company. This classification is regardless of the deterministic or probabilistic nature of elements;

7. **Impact** of a relationship, in general terms, can be *positive* or *negative* with respect to the other relationships or elements. However, by taking the quality of impact into account, it can be high (*significant*), medium (*moderate*), or low (*minor*). In practice, it is often difficult to explicitly measure impact of relationships using implicit or tacit knowledge. However, the sooner impact of a relationship determines, the more opportunity is to mitigate its negative consequences;
8. **Passion**: this latter criterion aims to address the main motivation for creating a relationship, and can be a kind of *interest*-based, *right*-based, or *power*-based. For example, the relationships between who are working in the same discipline within the same organisational level are usually interest-based or right-based, while those hierarchical relationships might be more power-based.

Some of the above aspects might more straightforward to figure out such as dimension, nature, and source. Some others like likelihood, impact and passion can be more problematic in practice, due to for example subjectivity in data, i.e., how to distinguish power-based and right-based relationships? Or how to explicitly measure the *impact* of each relationship on the consequent elements. As far as the scope of the paper allows and to avoid too much complexity of the simulation model, we recognised four aspects of *dimension, source, likelihood, and impact* to address company needs. This comes from the output of our first workshop with the company partners as part of which participants were asked to assign weight to the above criteria, based on the company preferences. Accordingly, the relevant information collected during the two following workshops and used during the formulation and simulation of the model.

4 THE PROPOSED METHODOLOGY AND APPLICATION

In this section, a methodology presented to address the above challenges in dynamic modelling of multi-layered multi-facet relationships. An example adopted from the business delivery process of the company to run the simulations and validate the results.

4.1 Case study

We draw the modelling and analysis on a case study of BT broadband delivery system. The ultimate goal is to offer and deliver the highest quality service to the customer while balancing cost and time. The process starts with customer request for a new service or modifying an existing service. Depending on the complexity of the order, it might be quickly solved through self-diagnosis of the problem or registered the order as a new job (e.g., installing a new broadband service) that should be carried out at a specific time. As shown in Table 1, complexity and challenges can stem from many interrelated sources at different organisational levels.

For example, efficiency of job planning system can be influenced by long-term issues at the strategic level (e.g., changing business strategies) and at the same time, by short-term issues at the operational level (e.g., shrinkage and sick leave, faults). The accuracy of job forecasting system therefore plays a significant role in creating congestion in the process. More work than expected can result in more work stack and overtime jobs, reducing productivity along with less job satisfaction. Eventually, it brings unhappy customers and reduced revenue. On the other hand, less work than expected can raise major issues pertaining to the increase in idle time, reduced productivity, and so increased employee cost. However, at the same time, it makes customers happy and increases the revenue.

By taking the above challenges into consideration, BT is interested in understanding sources of dynamism and (cost-based) risks that can affect system behaviour (particularly efficiency and effectiveness of the process) so that can use the information in the Service Operations Planning. It means to maintain steady work stack to avoid failed target while bringing customer highest service experience. Our case study aims to help compromise these competing concerns.

4.2 Model development and simulation

From a modelling perspective, it is difficult to capture the dynamism of multiple aspects of relationships in a single simulation environment. So we proposed a hybrid methodology that has three advanced modelling tools embedded: Multiple Domain Matrix (MDM) (Browning, 2015), Change Prediction Method (CPM) (Clarkson et al., 2004), and System Dynamics (SD) (Sterman, 2001). Each of these techniques is concerned with delivering a specific range of information that can complement the previous phase, while acts as the requirement of the next phase: MDMs are responsible for *representing quality* (*complexity*) of relationships through mapping multiple aspects; CPM is responsible for *identifying appropriate quality* of relationships through designing and analysis of experiments, and SD is responsible for *identifying mechanism of relationships* through explicitly mapping of key decision points. The outline of the proposed methodology is depicted in Figure 1. It has four phases named "Explore. Map. Reflect. Analyse" (E.M.R.A). These phases are briefly described in the following and their step-by-step simulation is presented Figure 2.

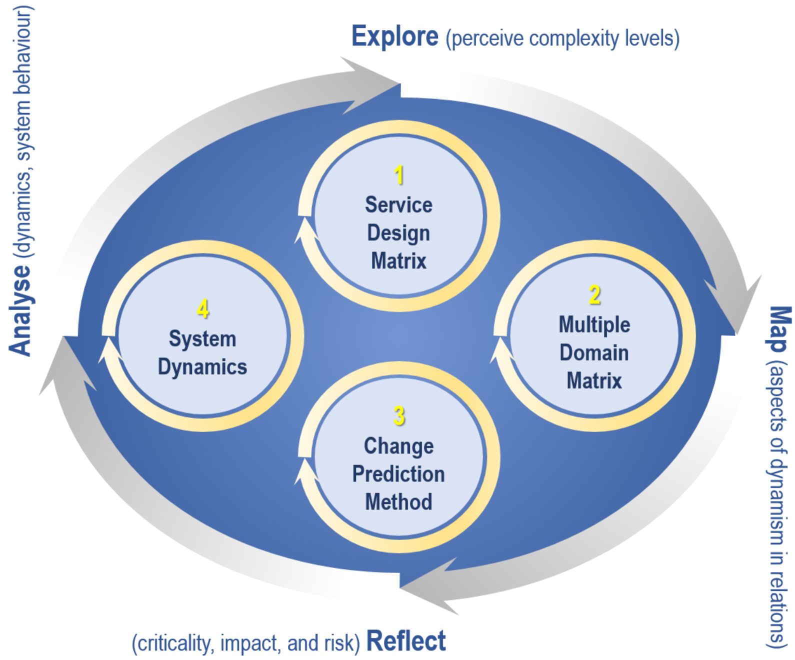


Figure 1. The proposed methodology for modelling dependencies in a complex system

Explore. Starting at system level, the model decomposes the entire system into multiple interconnected building blocks (SDM in Table 1) to identify potential sources of complexity in the current state of the system (AS-IS), and makes sure that all aspects of service design system (i.e., organisational levels, multiple stakeholders) are taken into consideration. Each box of the matrix is associated with a particular aspect of the process. For example, employee-related elements at the tactical level might be pertaining to as such operations planning elements such as people's availability, and job allocation system. The outcome of this phase provides the baseline for mapping and analysis of the relationships in the next phases (Fig. 2-a).

Map. Keeping aspects of the dynamism of relationships (Section 3) in mind, this phase can provide a detailed understanding of multiple forms of relationships between elements. We proposed a heuristic to achieve this goal; through increasing the degree of granularity and developing an MDM associated with each aspect of relationships; one matrix for each aspect. In the first two workshops in the company, three matrices generated to cover three aspects of *dimension* (direct or indirect), *likelihood* (infrequent, frequent, or certain), and *impact* (high, medium, or low) (Fig. 2-b, c, d), by asking the participants to fill up three different matrices. A color-coding scheme used to accomplish the tasks: Red (to identify certain likelihood and high impact), Orange (to identify frequent likelihood, and medium impact), and Green (to identify infrequent likelihood, and low impact). The information then transformed in DSM toolbox of Cambridge Advance Modeller (CAM) to be used in the analysis of impacts and risks in the next phase.

Reflect. Previously the existing relationship between any two elements along with their associated likelihood and impact have been understood. However, to establish the mechanism of relationships in a complex service system, it is significantly important to understand *what* elements of the system are subject to changes and at the top of that, to understand *how much* these elements are likely to change, and in the case, what would be their impact. To address these issues, the CPM toolbox of CAM used to understand the compound risk of the elements pertaining to the likelihood and impact of their relationships with other elements (Fig. 2-e). In fact, CPM in this context can act as a tool for Design of Experiments (DoE) that enables the modeller to proactively identify the riskiest elements and also reduce the subjectivity (e.g., in input data) from the methodology. As the result of applying CPM algorithm, 19 elements (out of 35) were recognised with the compound risk of more than 75% (Fig. 2-f, g). Such elements at the strategic level (brand value, churn rate) and operational (lead-time, early-life failure) levels represented more significance than the other at the tactical level. These so-called risky elements remained and then used in modelling the system dynamics.

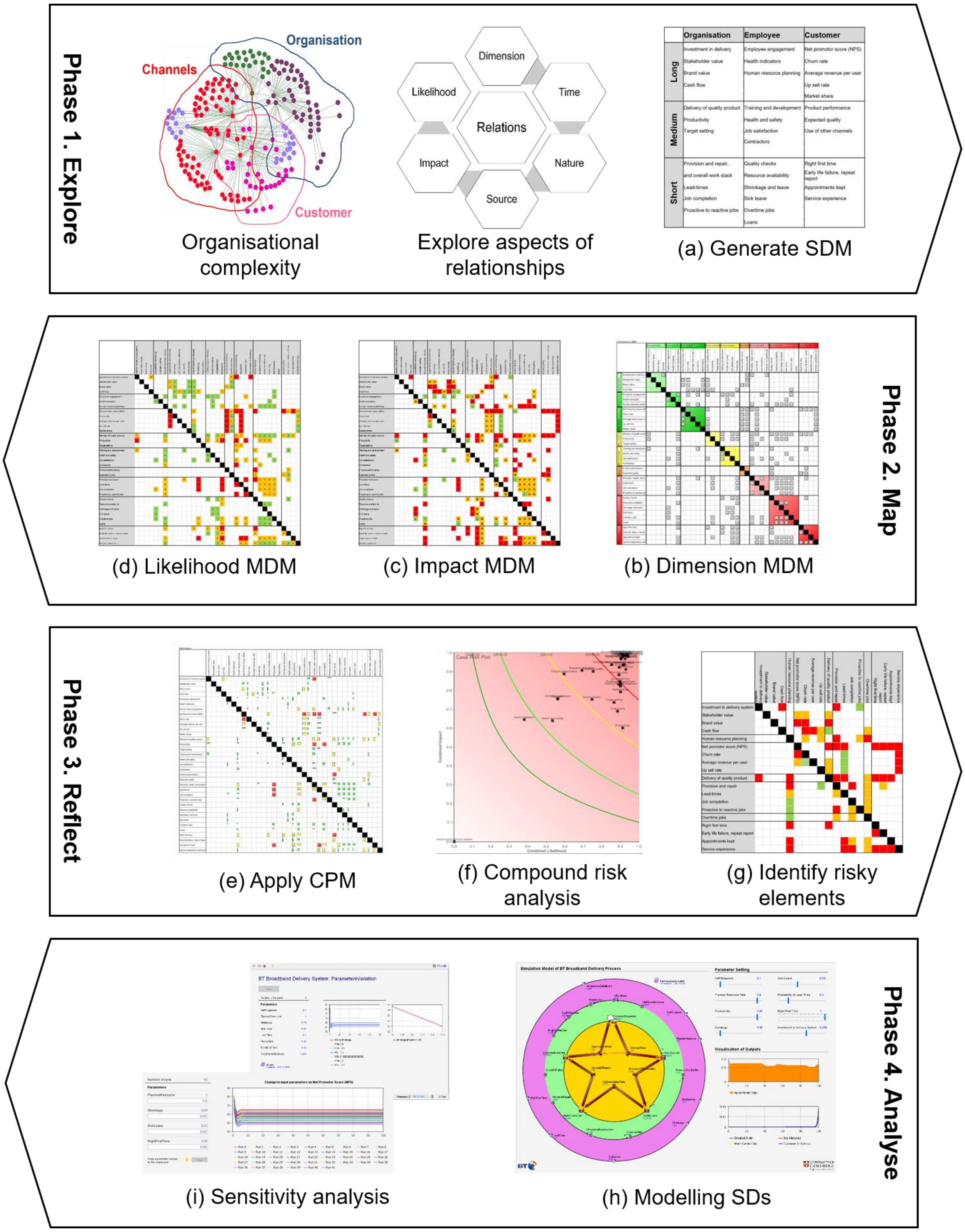


Figure 2. Step-by-step application of the proposed methodology in the BT case study

Analyse. At this last phase, we aim to analyse to what extent the relationships between the key elements can influence the other elements and the system behaviour. The objective is to draw a macro viewpoint of service design system that can help identify the key decision points. Hence, we kept the key elements come from the CPM analysis and used AnyLogic® to model dynamics of the relationships between them (Fig. 2-h, i). An interactive simulation platform developed, including the simulation model,

parameters setting, and visualisation of the simulation outputs. It was provided to enable the user to simultaneously change the parameters and see its impact on the outcomes.
Three consecutive workshops conducted to apply the proposed model to the company, each time by involving a group of 3-5 people. The first workshop dedicated to modifying and confirming the first two phases: explore and map. In the second workshop, based on the previous understanding of the relationships between elements, the data associated with likelihoods and impacts in CPM collected. The last workshop applied to verify the SD elements (including functions) and analyse dynamics of the system subject to change in the input parameters. Meanwhile, the participants were contacted by email asking for feedback on some points of the problem configuration and calibration.
Overall, the proposed methodology reflected acceptable utility in addressing complexity issues in service systems, particularly: effectively dealing with complexity of large-size problems (organisational complexity); uncovering hidden aspects of relationships (dynamism of relationships), especially when the decisions and the elements belong to different time-scales; and understanding those patterns of behaviours that can lead to successful business decisions (TO-BE situations). However, there are remained some issues that can affect the performance of the model pertaining to the degree of granularity of SDM; providing more reliable MDMs (preventing too many checked boxes); and subjectivity of likelihood and impacts in CPM. The following section discusses some areas in which functionality of the model can be improved.

5 DISCUSSION AND FEEDBACK

The methodology presented in this paper developed in response to the challenges facing the industrial partner: to anticipate change or failure in relationships and accordingly to track the source(s). The main reason might be the fact that relationships in large mature organisations often happen in multiple levels and affect the system behaviour under different circumstances. Through a systematic procedure, the earlier sections showed how to identify the most influencing elements and measure their impact on the overall system behaviour. A set of further analyses runs in this section to explicitly realise to what extent change in an element can affect the other elements and the process behaviour.
Adaptive in responding to changes. A separate simulation platform created to measure the sensitivity of changes in one or more parameters on the model variables. In the example shown in Figure 3, four parameters from different levels selected: Planned resource (at the strategic level), Shrinkage and Sick leave (at the tactical level), and Right first time (at the operational level). A set of 41 different scenarios then generated and ran to show the variability of Net Promotor Score (it is a measure of customer satisfaction) when some of the parameters simultaneously changed (with respect to their original input values). By clicking on any of the run numbers, the user can observe the input parameters and associated diagram. As the result, the percentage of *planned resource* and *right first time* represented the more impact on the NPS rate, particularly when changed together.

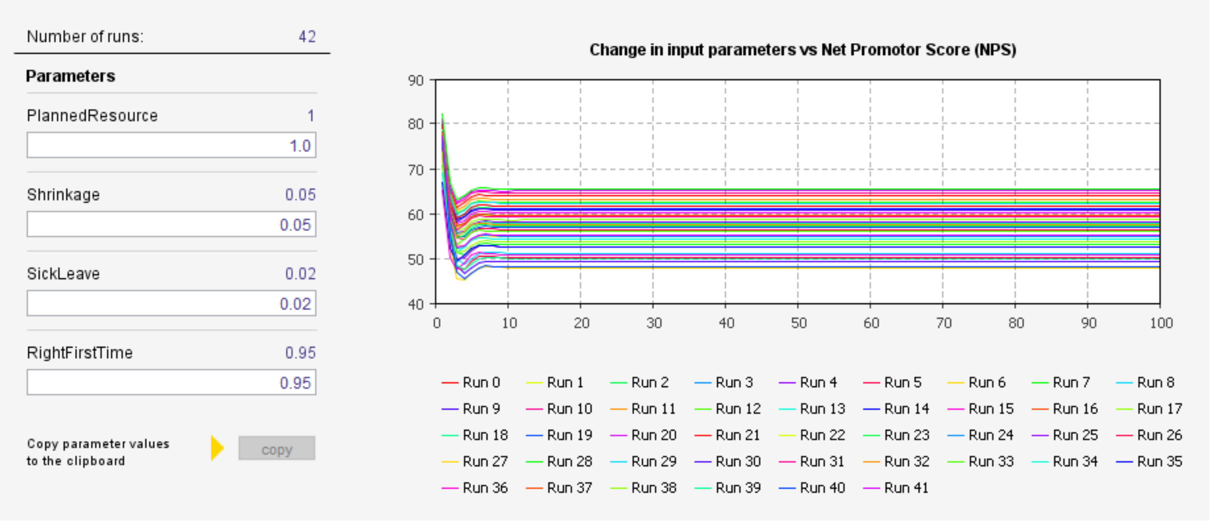
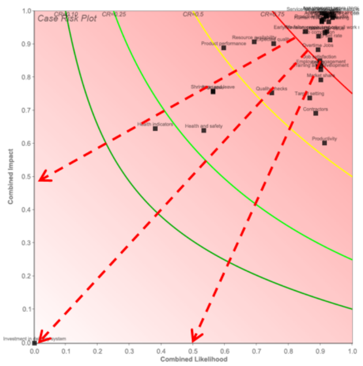


Figure 3. Analysis of change in one or more elements on the system behaviour (Net Promotor Score in the example represents the customer satisfaction rate)

From a practitioner perspective, these sort of simulation experiments would give a more realistic view of the possible outcomes that can be used at all strategic, tactical, and operational decision-making levels. The feedback from the company could confirm our findings. Rather than describing AS-IS situation to understand sources of dynamism, the methodology could suggest TO-BE situations support adaptive decision making in presence of unexpected issues. This functionality is particularly important when there is not a clear definition of information dependencies or the service process is not well-structured.

Robust in reducing subjectivity. The presumption until now was that source of dynamism is known (unknown known or uncertainty). This might not be always the case, for example, when likelihoods and impacts data are subjectively defined by people from different backgrounds, or when transforming the qualitative data into the quantitative ones to use in the software. In the latter case, different levels of impact (significant, moderate, minor) were respectively converted into 80%, 50%, and 20% for using in the CPM toolbox. A question might arise pertaining to how the combination of risky (key) elements might change if the conversion rate changes to 70%, 40%, and 10%? To test this hypothesis, a new set of experiments with the new scale of likelihoods and impacts (from 80-50-20 to 70-40-10) performed in CPM. The result of applying CPM algorithm is presented in Figure 4, as the comparative Risk Plots.



80-50-20	Risk Level (RL)	70-40-10
1	0.00 < RL <= 0.10	5
1	0.10 < RL <= 0.25	7
3	0.25 < RL <= 0.50	8
11	0.50 < RL <= 0.75	13
19	**0.75 < RL <= 1.00**	**2**

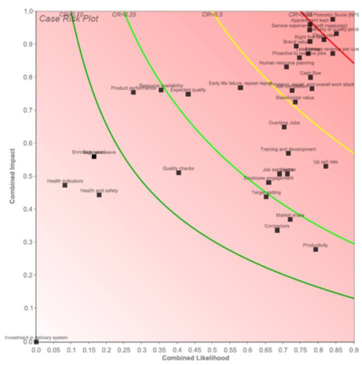


Figure 4. Impact of change in scaling data on the outcome of CPM algorithm

By changing the scale of qualitative data, the number of risky elements (compound risk of above 75%) significantly reduced from 19 down to 2. However, the overall shape of risk plot seems to be similar and the elements are to transform downward the diagonal. Likewise, the more experiments might be of more practical use to change only the scale of likelihoods or impacts and then compare the position of elements in the risk plot diagram, and consequently the configuration of system dynamics model. This range of experiments can give the most appropriate set of elements, as robust as possible, that should be transformed into system dynamics.

6 CONCLUSION

The preliminary of the paper discussed the challenges to model and analyse levels of relationships in large complex contexts. In response to these challenges, a multi-echelon integrated methodology presented and applied in the example of BT broadband delivery process. The objective was to explicitly understand the mechanism of relationships through which multiple stakeholders should interact, thus supporting business decisions. Combinatory use of advanced techniques in DSM (MDM and CPM) and system dynamics provided the model *scalable*, *updatable*, and *adaptive* enough so that can work with insufficient information or poor-structured product-service systems. Applicability of the proposed approach can be more than the presented case study, with the potential to apply to any kind of complex business process regardless of its product or service nature. To summarise its application:

- *Utility*: Not all information have the same importance. The proposed model can prioritise the information and help decision makers on what should the network of relationships look like;
- *Impact*: The practitioners found many interesting pieces of insights that should be passed to the particular range of audiences in the company. However, the group of Operations Management and Organisational Management could be the main targets of the model outcomes.
- *Limitation*: The proposed methodology is a kind of integrated framework that requires information from different disciplines at different organisational levels. In addition, different groups have also

different time frames on the SDS, so finding the appropriate level of granularity can be a major concern;

- *Direction*: Should be multiple stakeholders considered independently, there can be some areas of overlapping. So the authors are thinking of transforming the relationship directions to the relationship spaces. Enhancing the functionality of CPM experiments might be of additional direction.

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