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ACTOR-BASED SIGNPOSTING: A SOCIAL PERSPECTIVE ON MODELLING DESIGN PROCESSES

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1. Introduction

Modelling design processes (DPs) has always been a central issue in design research. Many researchers have attempted to understand the behaviour of processes by mapping them in static models, or by simulating them in order to predict future process outcomes. The matter can be highly problematic in presence of uncertainty, that is an inherent aspect of DPs, and that makes both process planning and execution of process difficult. Referring to typology of DP modelling, dealing with uncertainty, level of abstraction, industry-dependency, applicability in real-size problems and information richness are reported as principal limitations on process modelling [O'Donovan 2004]. The difficulty of modelling DPs has led to a variety of approaches proposed in literature (for review, see [Browning and Ramasesh 2007]), each one attempting to investigate specific aspect of DPs and characterized by strengths and weaknesses.

In fact, there currently is no generic and overarching model than can satisfy common features on various DPs and can therefore be applied to all kind of processes. In order to fill in this "versatility gap" and therefore provide better support to management, recently developed models have been mainly aimed at providing richer models of DPs by including a number of process characteristics [Wynn 2007]. But it is obvious that, by including more aspects and details of DPs, this results into models that are more complex and more difficult to manage during execution. The objective of providing "actionable" DP modelling frameworks that can be of practical use to design managers provides the main motivation behind this paper, i.e. to introduce a novel viewpoint on modelling DPs with a specific attention being cast on understanding the behaviour of actors involved in the DP, along with their mutual influences.

The philosophy behind the proposed model rests on the one side on established analytical approaches [Wynn 2007] that view DPs as dynamic task models made up of a sequence of process activities with detailed characteristics. On the other side, on a representation of the social network of designers involved within the DP and who interact and negotiate among themselves. Literature has up to now investigated various sources of uncertainty, mostly in relation to technical performance and timing. We can view the main contribution of this work to be the inclusion of interactions among designers assigned to design activities. To our belief, this element can have a strong impact indeed on the DP. As a starting point for this work, we have adopted Signposting [O'Donovan 2004] because of its capability of capturing different modes of iteration and of uncertainty. This paper therefore proposes "Actor-Based Signposting (ABS)" as a new perspective and an extension of this established process modelling framework. As central to this version, role of actors, specifically their negotiation and interactions, is investigated in an integrated view with an actor analysis tools. In section 2, common challenges on modelling DPs are investigated. Section 3 reviews the evolutionary process of the Signposting method. The proposed model is presented in section 4, with a focus on its functional elements, and finally, section 5 concludes the paper with remarks on future research directions.

2. Challenges on modelling design processes

During the last decade, DP modelling has been transformed quite radically from the simple objective of describing a process in order to understand it or rationalize it, towards the objective of providing practical support during the execution of the DP itself, by predicting the future behaviour, given uncertainty and unpredictable changes. In this way, along with a great maturity on DP modelling, such tools like CPM and PERT are no longer considered to be usable, due to the iterative nature of DPs [Pahl and Beitz 2003]. From a project management perspective, it is recognized that DP are activity networks with iterations, and methods such as queuing models, IDEF and DSM are therefore preferable [Browning et al. 2006]. However, while these models are fairly accessible and able to represent very large processes, they suffer from industry-dependency, as it is difficult to restructure the model for other process types; in the case of activity DSM [Browning 2001], interpreting the model is also an obstacle that can limit its applicability (for review of frameworks, see [Browning and Ramasesh 2007]). A number of discrete-event approaches such as Petri-nets and BPM have been introduced with the purpose of modelling and management of the workflow and for which many software tools have been developed [Browning et al. 2006]. However, there appears to be an issue with the maintainability of these approaches, especially for complex systems. Hence, several recent researchers have attempted to improve these models [Karniel and Reich 2011].

Nonetheless, by looking inside the specifications of each model, it is indeed difficult to cope with all the challenges facing DPs through a generic framework. Some of them, like System Dynamics and Queuing models, are more flexible and updatable [Wynn 2007], but their high level of abstraction does not allow them to deal with different levels of uncertainty. The opposite holds for more detailed models, like Petri-nets and activity DSMs [Karniel and Reich 2011]. Among the aforementioned proposed DP models, dynamic task models like Adaptive Test Process [Levardy and Browning 2009] and Signposting [Clarkson and Hamilton 2000] are widely considered to fit the requirements in dealing with uncertainty and information richness, thanks to their dynamic detailed construction. However, lack of applicability to large-size problems and their industry-dependent structure are also viewed as a constraint to the diffusion of these tools, in spite of several extensions to the original Signposting method [Keller et al. 2006]. Therefore, there still is an issue to come up with a support for DP that is able to efficiently apply to dynamic large-size processes.

Apart from level of granularity, maintainability and applicability, level of connectivity (interactions) is a critical issue in modelling complex DPs, and is involved as a source of uncertainty in a wide range of approaches. While some of these models were successful in mapping multiple levels and sources of dependency between product components [Flanagan 2006], [Danilovic and Browning 2007], [Romero et al. 2008], they lack capturing the interactions and negotiation between people involved in the process. On the other side, from a social network perspective, dependency between actors was a major contribution in such a frameworks like agent-based models and IDEF series [Kim et al. 2003], [Wang et al. 2009]. Since mapping the level of interaction has a direct effect on complexity of DP, this is nonetheless challenging a structured methodology to deal with direct/indirect types of interactions from both viewpoints of product components and actors (e.g. designers).

3. Baseline on developing a support for DP

3.1 DP as social network

The social aspect of DP can be stemmed from the term actor-network idea, which is involved socio-technical process of negotiation [Walsham 1997]. It means a network of actors with interactions and negotiation among themselves. These interactions not only affect complexity of DP, they also can influence the execution of other process activities. Hence, this is of particular importance to find the best fit of actors based on their negotiation power and position within social network. Furthermore, an actor-network consists of and links together both technical and non-technical elements [Walsham 1997]. Technical elements are those activities in relation to product components, and should be considered together with non-technical elements, which are related to actor behaviour, due to their reciprocal influences, i.e. a simple design task implements in various processing times with various usage of resources, by different actors (whom) and different ways (how).

From social network theory, an actor is a social entity, a person or an organization that is able to act on or exert influence on a decision, either directly or indirectly [Walsham 1997]. In the context of this paper, actor refers to any kind of audience involved in DP (e.g. designer, engineer, specialist, manager). Moreover, in the proposed model, actors are assigned through their qualifier confidence level (in signposting system), while this procedure can be supported by a selection policy based on an actor analysis tool like MASAM [Chea and Bui 2004] and DANA [Hermans et al. 2012]. The benefits for this conjunction are twofold: First, provides better adaptation in dealing with uncertainty of people interaction and negotiation, and second, enriches actor selection policy, since actor qualification decision (based on input qualifiers data) is supported by actor analysis tool during process, and facilitate the actor assessment procedure. This subject will be later explained in section 4.

3.2 Signposting system and its evolution

Given the discussion in the previous section 2, we have decided to build on the Signposting methodology rather than attempting to develop a new approach from scratch. In fact, besides being a widely known and tested methodology, Signposting lends itself quite well to being extended from its current focus on activities to our intended focus on designers in charge of the same. In order to explain the type of extension we are proposing, the following discussion will provide the way with which Signposting has evolved over the last years.

Structurally, Signposting is a kind of dynamic task-based models of DPs, aiming to outcome a sophisticated sequence of activities based on their information input and output characteristics. This is done through the concept of "current confidence" for a set of tasks, as an indicator of parameter state, and in which output parameters of a "source task" are used as the inputs for "sink tasks". The original Signposting was developed by the Cambridge University EDC as a response to the challenge of modelling helicopter rotor blade design at Westland [Hamilton et al. 1997]. The main goal was to address "what to do next?", providing guidance for designers that was done by color-coding tasks based on four contextual levels of confidence [Clarkson and Hamilton 2000]. Due to the potential confusion on choosing tasks at any point of the process, given the high risk of rework between possible tasks, an improvement was carried out by Melo [Melo and Clarkson 2001] by defining an optimum task ordering. This was carried out by selecting the most appropriate option by means of Markov chain analysis, with emphasis on the whole route of process instead of only the next task. In parallel to the model developed by Melo, Jarrett [Jarrett and Clarkson 2001] applied Signposting on conceptual design of jet engines, integrating the functionality of Signposting with industrial design tools. In this paper, the concept of confidence improved by identifying a "confidence matrix" that could dynamically be updated at any instant of the DP.

In order to make Signposting applicable to real cases, an "Extended Signposting" was proposed by O'Donovan [2004]. The author attempted to add detailed features to the model, and specifically multi-class resource constraints and in-process learning through parameter evolution. As the complement to what Melo proposed on parameters mapping [Melo and Clarkson 2001], in Extended Signposting, modelling non-Markov processes allowed by dedicating numerical levels to parameters that enables model to consider all types of real-life parameters. Moreover, in comparison to previous versions, Extended Signposting could capture multiple possible outputs with different degrees of success, and also estimate the impact of different inputs on possible outputs. Nonetheless, this research was later criticized by Flanagan [2006] who highlighted two drawbacks of previous work with specific attention on modelling dependencies and parallel tasks. The core of model was dealing with project planning and representation through investigating the effect of different sources of uncertainties, process properties like scale and connectivity, and the product-process link as interdependencies.

In order to make Signposting applicable to large-size cases and independently from industry type, Wynn [2007] suggested improvements with a focus on elicitation through process modelling and simulation and also model representation by understanding various modes of iteration. He used a sophisticated hierarchical structure of tasks and parameters as a support to model presentation enriched by a user-friendly platform. However, due to information-driven nature of model as a task-precedence network, the model would be more suited to categorize as DSM tool rather than Signposting. Overall, research into Signposting [Wynn 2007] attempted to overtake the problem of tacit knowledge on DP through more focusing on dynamic behaviour of process and supporting owners and management with multi-aspect representation tools; however, different interpretations on the meaning of confidence, signposting construction and representation policy are always key challenges when implementing Signposting [Flanagan 2006] which implies continuous effort on process modelling (Figure 1), but more detailed versions of this approach may result more complex system that would be difficult to manage all events consequently. Therefore, attempts should be shifted to more integrated and automated systems to make it applicable in practice, due to the fact that finding out the right model for process management has been always a controversial issue [Heisig et al. 2009], specifically for decision makers.

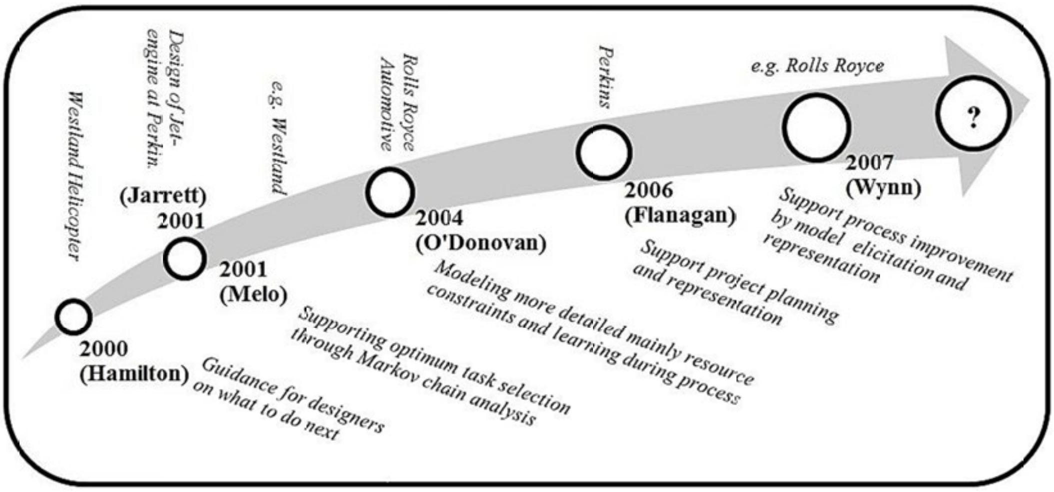

Figure 1. Evolution of Signposting system

4. Towards Actor-Based Signposting

4.1 Specifications for developing an approach

When managing the design process, Signposting can provide a useful guidance mechanism that focuses on tasks and their reciprocal interactions, leading to the progressive refinement of parameters. The method supports designers by pointing out (or "signposting") what to do next, but essentially considers them as mere executors of the tasks. We posit that, if one shifts the focuses on designers, by highlighting a sequence of tasks that can be performed, this opens up an organizational and social process within which the designers will have to interact more or less directly, and negotiate a solution that can be considered satisfactory. In this context, "satisfactory" is related both to the degree with which the involved designers perceive the outcome of their work, and to the degree with which the same outcome complies with the constraints cast by the rest of the design process. The way by which this process will occur, will in turn depend on the pattern of mutual relationships between designers and their reciprocal influences. The guidance provided to designers and design managers can therefore include not only the content of the work, but also hints on how to carry it out (e.g., highlighting possible breakdowns, understanding who are the designers with a key role, etc.).

Hence, referring to the Signposting system, we aim to extend the paradigm from the management and control of a large amount of activities in a complex system to the creation of a set of rules and hints for the actors that are involved. We consider that, by highlighting the responsibility of actors, this can contribute to feeling greater ownership of the work being done and to be more responsible on their achievements and on the process. Besides, for practitioners, the model will be helpful to find out whom to communicate with, rather than having the model facilitating the communication message [Heisig et al. 2009]. In other words, we aim to answer this question; who are the right actors involving on the process for to do what task(s) with respect to the objectives of process and what should their role be?

Original Signposting assumed DP as a series of tasks concerned with the identification, estimation and iterative refinement of key design and performance parameters, until a sufficient level of confidence in those parameters is achieved [Clarkson and Hamilton 2000]. The core elements of model are parameters, states and tasks that affect directly the level of detail and complexity of modelling processes. These core elements are updated by adding actors in the proposed version that will be explained later in the next subsection. Let us call the proposed approach as ABS henceforth. The ABS technique intuitively considers DP as the collaboration of actors with their corresponding activities and therefore views the DP as a set of highly interconnected actors and activities with mutual influences concerned with identification, estimation and iterative refinement of key design and performance parameters, until the best fit(s) of actors-tasks are achieved satisfying those parameters confidence. Figure 2 shows the outline of ABS in comparison to previous versions. Nowadays projects are to a large extend influenced by deadlines, resources and capacities, theses boundaries are dynamically updated in the model, while actors as responsible for activities can affect each other and also others activities through discussion and negotiation.

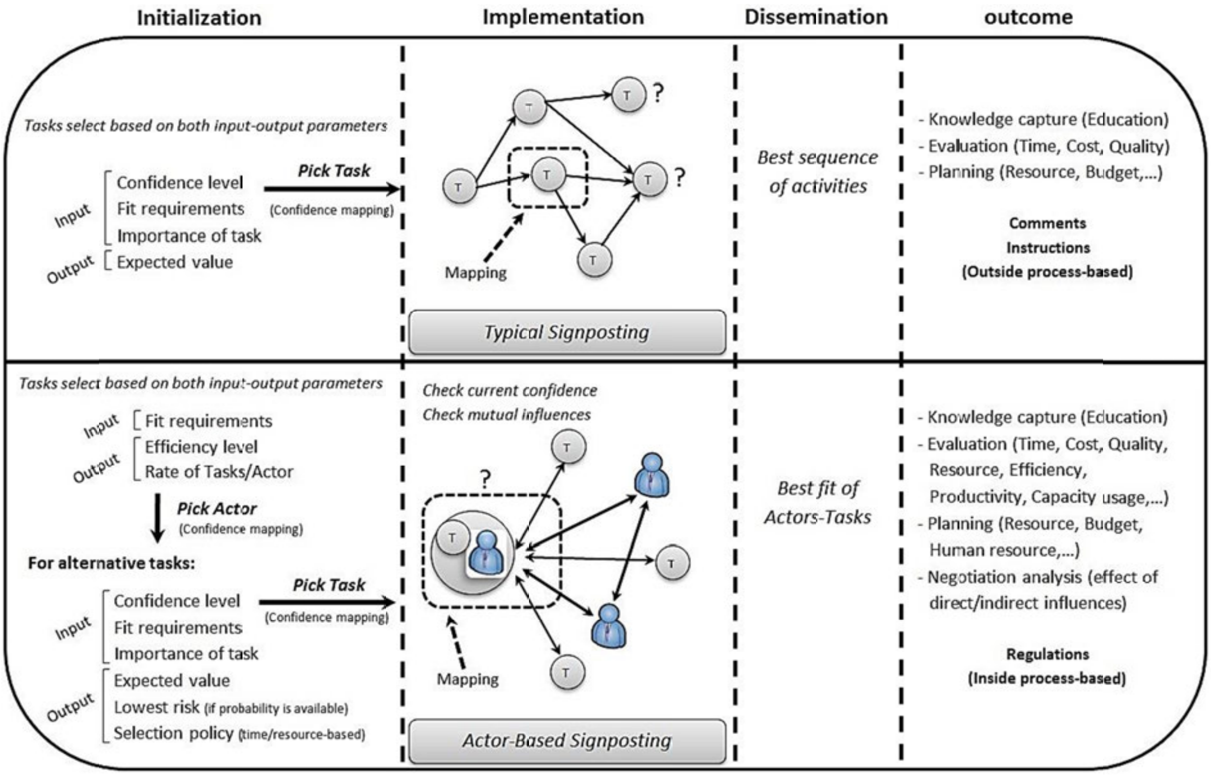

Figure 2. Actor-Based vs. Typical Signposting outline

As mentioned before, of utmost importance for practitioners would be to understand who should do what, which means the best fit of actors-tasks. Regarding to the role of people in DP, previous versions of Signposting considered people as audience of model and in a more detailed manner, as a resource on task mapping. Here the influence and power of people in process is obviously missing. Instead, our aim is to structure an information mechanism allowing actors to better understand the social and organizational process that is activated when a sequence of design tasks is called for. The mechanism must act in order to allow actors adjust their behaviour, rather than performing actions determined centrally. So the model should be more predictive rather than only describing the behaviour, with respect to the role of uncertainty. This will be done through filtering alternative actors and tasks by assessing their both input and output requirements as well as fitness, and providing dynamic updates also based on the current state.

In ABS model, filtering alternative tasks and actors is done through minimum confidence level. Task execution affected directly by actor behaviour and technical performance. Hence, in order to enhance trustworthiness of actor selection policy, especially in iteration loops, we combined Signposting confidence concept with an actor analysis tool, called multi-issue actor strategic analysis model (MASAM) [Behdahan et al. 2005]. This technique makes ABS actionable for DPs with respect to actor performance and interactions, and will be updated dynamically and iteratively. Figure 3 depicts the step-by-step ABS system. There can be some additional advantages as outcomes for the proposed model in this integrated view, i.e. facilitate and improve actor selection procedure, identify critical actors and their assigned responsibility to each task, facilitate information flows within process, considers multiple levels of dependency between actors, and managerial insights for human resource management (HRM). The MASAM technique will describe in the next subsection 4.3.

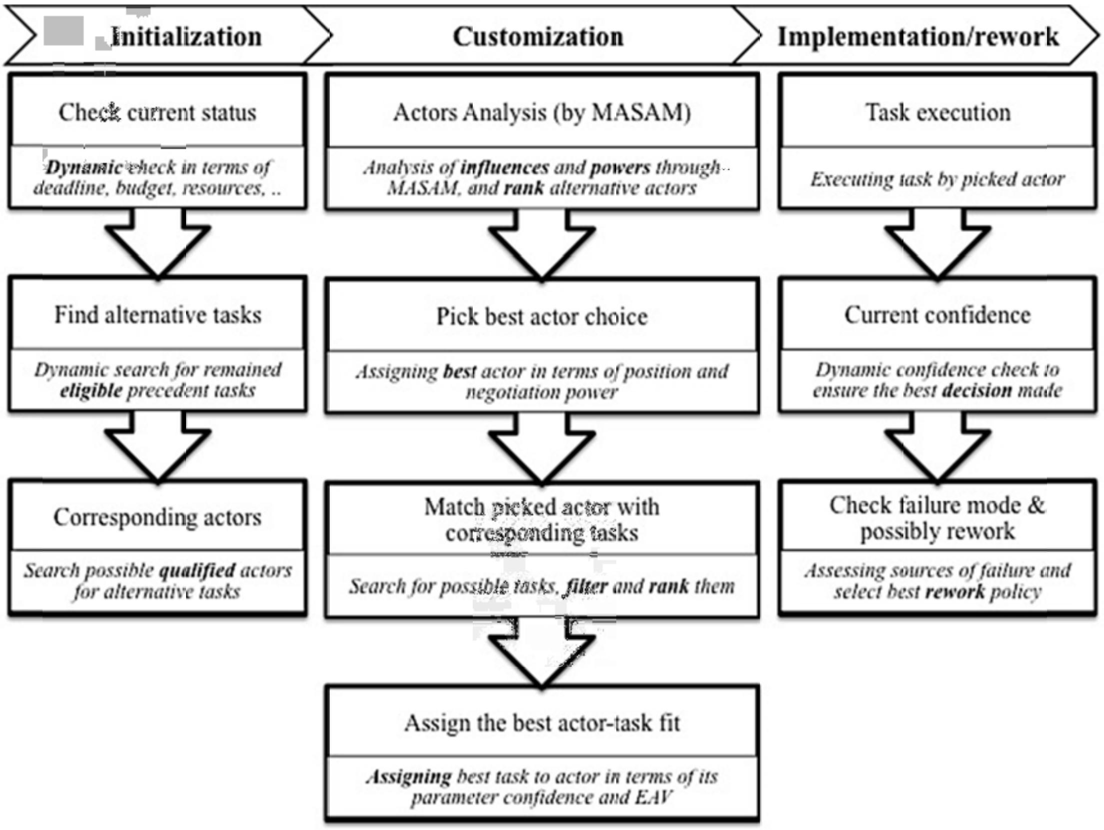

Figure 3. Step-by-step ABS system, integrated view with actor analysis tool (MASAM)

4.2 Construct of proposed model

This subsection concentrates on the proposed model, specifically identifying the core elements and their functionalities. These elements are known as pillars of Signposting, since the level of granularity, flexibility and so complexity of models are heavily depended on their initialization. In following, players of the model are considered in details.

4.2.1 Parameters

Signposting is basically a parameter-driven system [Clarkson and Hamilton 2000], where the permission of either tasks or actors is issued based on their confidence level on those corresponding parameters. The aim is to run activities with the highest possible confidence level, which means increase in quality. Since the extended version by O'Donovan [2004], a "parameter" in Signposting refers to any kind of elements related to DP. Following the example in Figure 4, each parameter is composed of an "identifier" and a "qualifier". Identifier is the pure name of the parameter per se, supplemented by additional information (e.g., Bike Wheel or Peter Johnson), while qualifier refers to the level of quality or maturity of the parameter [O'Donovan et al. 2003], and use in place of the actual value of the parameter, and is differed by parameter type.

Given an example of process specialist, the parameter representation is depicted as in Figure 4. The goal is to identify whether he is qualified enough to work on a machine named X, and presumably, higher levels of confidence leads to the better quality of activities done. In this context, the level of learning and particularly, his knowledge on machine X is known as the parameter, with the educational level introduced as qualifier. Suppose the Bachelor is the minimum level of qualifier to work with machine X that means level 2 of confidence value. So the actor is allowed on machine X, only if he passes the educational level (qualifier) of at least 2. By passing this qualification stage, all actors and activities are authorized to run within process, while iteration occurs for opposite manners.

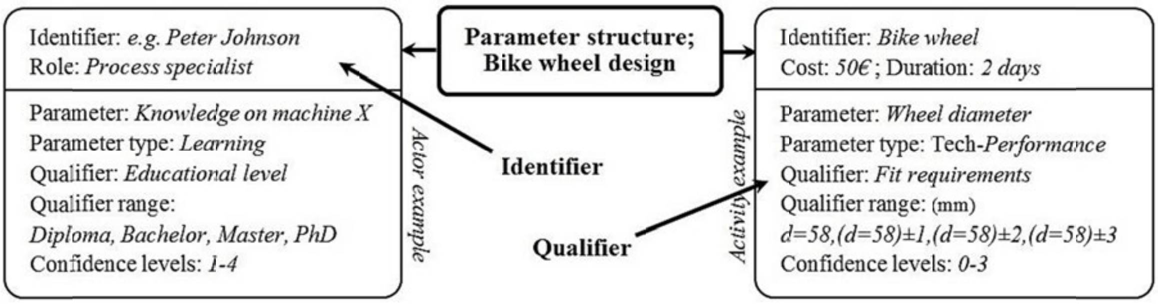

Figure 4. Construction of parameters in Signposting

4.2.2 States

The complete set of all parameters and associated qualifier values at any instant in time defines a process state [O'Donovan et al. 2003]. It can be a kind of criteria on activity done in the scale of DP that represents how much work is remained to finish the process. Traditionally, two kinds of input and output states are identified as the frontier of DP (Figure 5), but in the context of ABS, the model is supplemented with the current state in order to better indicate dynamic behaviour of undergoing activity. While input states are referred to tasks before running, after starting the implementation of a task, it is also possible to occasionally check the requirements of a task in comparison to its input state, to providently ensure the added value by execution of the task, and inversely to prevent wasting time and resources for unfitted actors or tasks. In other words, it has two-sides benefits; one is to track the dynamic behaviour of the process in terms of performance and timing issues (e.g. new deadline, resource, budget), and the other, keep managers update on preventive actions in the case of failure or resource constraints at any instant of process.

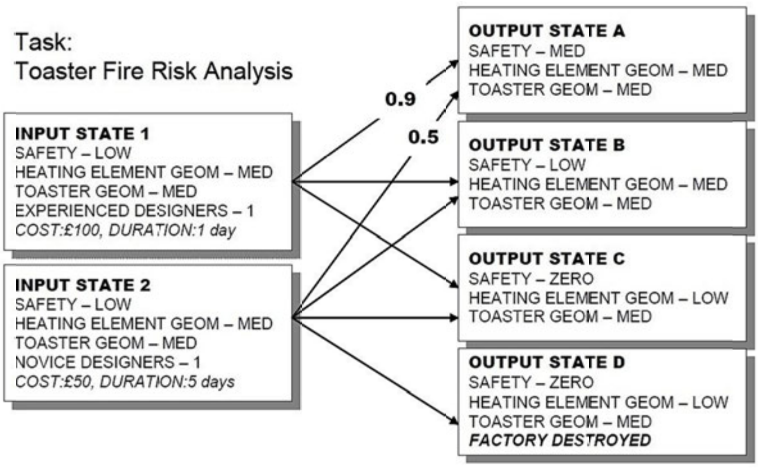

Figure 5. States and their mapping (adapted from [O'Donovan et al. 2003])

4.2.3 Tasks

In Signposting, each task is represented as a package consisting of a number of elements as mapping, input state, current state, output state and additional information. The number of each of these items can affect directly the complexity of modelling. In an improved Signposting, normally there is more than one input mapping, each one with a probability to result a specific output. In Figure 5, as an example, different resources (experienced and novice designer) resulted various outputs for each input state. As a rule, the confidence level for each input state should be less than current state and alternatively than output one, in order to select the task. Following Figure 5, for output state C, which is done by experienced designers, two of three parameters have the confidence level of less than input (Safety; low→zero, and Heating element geometry; med→low) within which the task is failed and led to rework/failure, while inversely for the output state A, the requirements are satisfied and passed, with the probability of occurring 90%. In the sense of current states, the pattern is similar and means; execution of task is promising only if, all set of parameters for current state had better confidence level rather than the input state. In ABS technique, the interactions between functional elements and their consequences are of more attention in task mapping, in spite of technical performance and timing.

4.2.4 Actors

Representation of actors in proposed ABS is similar to what for tasks, in terms of input, current and output states, along with their mappings. The mechanism for identifying the probability of output states is fairly compatible to tasks; however, the correlation between functional elements as the result of negotiation between people can affect their way of executing tasks. This is the aim of our work, to cope with mutual influences between actors and consequently their effect on other activities. Of interest notation here is that actor representation based on confidence levels is mainly embedded in initialization step (Fig. 3), based on the knowledge of previous process or iteration. Qualified actors later will assess during ABS system and rank through MASAM tool, to support confidence outcomes, and also to fully capture information flows between actors.

Structurally, four types of interaction are considered into ABS technique; influenced by other actors (Direct negotiation), influenced by other tasks (Indirect negotiation), influenced by both other actors and tasks (Full negotiation), and non-influenced by others. These types are exemplified through Figure 6, given the example for a process specialist, who is responsible on Bike wheel design by means of approximate time and resources. Following the figure, here is assumed that surrendering the job is the only result of influencing by other actors. On the other side, influenced by other activities, time and resources of activity are changed. The two other possibilities are related on affecting by both other actors and activities that cause some changes on actor, time and resources, and the non-influenced situation. For each of these manners, tasks mappings are existed made up of various input and output states, through which, from overall process perspective, there should be a balance on interactions mapping and complexity of the model.

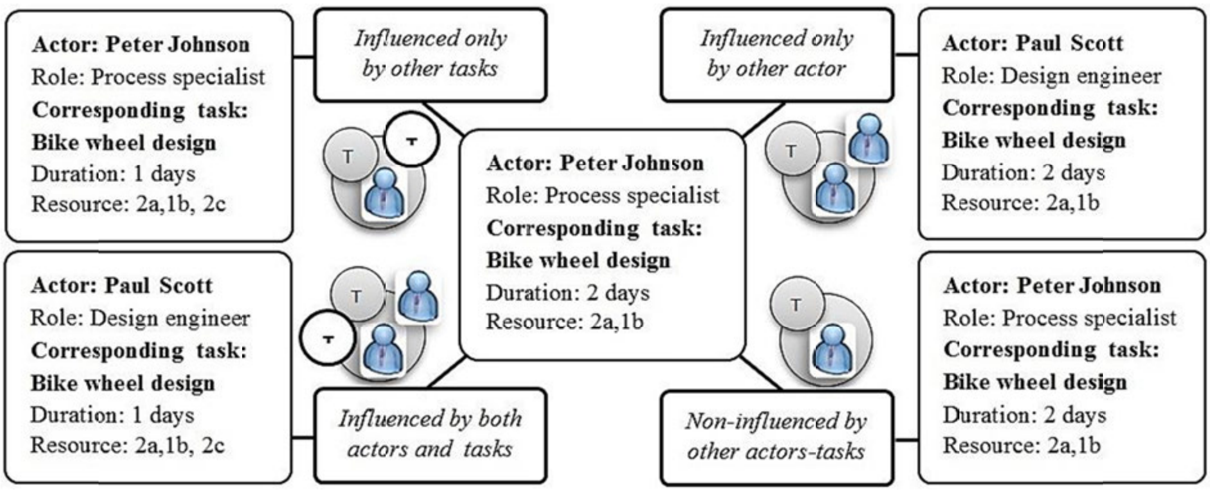

Figure 6. Exemplifying actor mapping with different types of interactions

4.3 MASAM

Emerging the merits of two former negotiation models, proposed by Godet in 1991 [Godet 2001] and Allas and Georgiades [2001], multi-issue actor strategic analysis model (MASAM) [Bendahan et al. 2005] introduced as a decision support tool to handle flexibility of influences for large scale negotiation that involves many actors on numerous issues. Established on the MACTOR model [Godet 2001], MASAM postulates that diverse participants with divergence of interests and powers try to influence other participants (actors) through their personal preferences, in a set of issues. Of crucial importance in MASAM algorithm is the relationship between actors and issues that should be evaluated to reach the ultimate goal of analysis tool, and this would be derived from a set of four matrices: position, salience, clout, and influence. In the context of this paper, we aim to identify the position and negotiation power of each actor as the outcomes of algorithm. This information helps us to rank actors and assign the corresponding and qualified task(s) to each. Besides, since MASAM algorithm also supports issue analysis, it can open out a structured assessment of actor input qualifiers, helping us to identify the best fit(s) of actor-task as the final outcome.

5. Conclusive remarks and future directions

The paper has presented the opportunity and potential basis for an extension to the well-known and widely accepted Signposting method. Given a DP as a sequence of tasks, focuses shifted from tasks to actors in this work, by highlighting the mutual relationships between designers and their reciprocal influences. The aim is to extend the paradigm from management and control of a large amount of activities in a complex system to the creation of a set of rule and hints for the actors, by finding out the best fit(s) of actor-task in executing the DP. From a practitioner viewpoint, specifications of the model should intuitively disseminate satisfactory outcomes with attention on visualization of dynamic behavior. Since the requirements of model can affect directly its outcomes, it is highly recommended for further research to identify better the requirements of ABS technique. In this paper, an actor analysis tool is recommended to integrate with Signposting confidence theory, to deal with uncertainty of DP as the result of mutual influences between participants. To our belief, the proposed model has potentially the benefit of supporting managers and decision-makers a wide variety of supplementary outcomes like such a kind of outputs in relation to the right actors' selection, their responsibilities, their affect on other actors and tasks, the right corresponding tasks to each actor to do, that can be further investigated in development phase.

The paper theoretically attempted to construct a basis for ABS method with focus on functional elements of the model, which is supported by an actor analysis tool. In this way, a conceptual framework is proposed as an outline to the execution of the model, while further research is needed in the near future to come up with development and validation of the proposed method, especially in real-life settings. Structurally, model can widely cover any types of audience in relation to DP and their direct/indirect influences. To our belief, the integrated and predictive nature of ABS approach can support designers with detailed characteristics of DP (multiple dependency, failure modes, resource constraint, stochastic durations, etc.) as well as process behavior (learning during process, system analysis support, process planning support, etc.). Nonetheless, for practitioners, the satisfactory assignment of actor-task would be of more interest. ABS initializes with checking the requirements on execution of the process (e.g. available time, resource, budget), while finalizes by checking failure modes, with the dynamic exploring of mutual influences in central. The process iteratively continues in order to find the best fit(s) of actor-task. Nonetheless, due to important role of social networks on DPs, the paper aimed to open an avenue through a new perspective in process modeling, while development and validation of the proposed method is remained for further researches.

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