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A DYNAMIC BUSINESS MODEL FOR COMPONENT-BASED SIMULATION SOFTWARE

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ABSTRACT

Firms, investors, venture capitalists, market analysts and the government, amongst others, are interested in the future evolution and dynamics of a market as it defines their role/participation or future role/participation. This paper proposes a business model showing how the interactions of various actors in the market influence the "demand" and "supply" interaction for an application based software; more specifically component based simulation. In the process we also show how the main stakeholders may gain some financial benefits by adopting the component-based simulation for business decisions in the long run. We identify four main stakeholders: component users, component providers, certification providers, and repository providers. A system dynamic model is built to show the interaction between the two main stakeholders.

1 INTRODUCTION

There have been numerous applications of Component-based simulation (CBS, thereafter), such as Zeigler (1987), Daum and Sargent (1999), Verbraeck (2004), and Spiegel et al. (2005). CBS is attractive in that it has the features which allow it to fit and adapt to the desired future simulation software (Oses 2002). Those features are summarized in Table 1 and are further categorized the features into three levels.

Table 1: Desirable Features of Future Simulation Software

Levels	Features
Modelling	Modularity, Reuse, Hierarchical structures
Simulation systems	Scalable, Portable, Interoperable
Implementation	Distributed execution, Execution over the Internet, Easy to use

As systems being modelled grow larger and more complex, it is desirable to reduce the complexity of a large problem by breaking it into more manageable pieces (*modularity*). Software *reuse* is defined as the isolation, selection, maintenance and utilisation of existing software artefacts in the development of new systems (Pidd 2002). Reuse is raising much expectation in the simulation community because it seems to promise more cost effective, faster development and easier maintenance of complex models (Daum and Sargent 1999). *Hierarchical structures* allow simulation model to be developed using recursive hierarchical composition (Daum and Sargent 1999). The system architecture or design should enable simulation software to work when the number of modules increases (e.g., the size of the problem is increased). It is important because the future simulation software must work for large-scale problems as well as small scale ones (*scalability*). Miller et al. (1998) noted that the system architecture or design should enable simulation software to run without modification in different platforms, with different hardware and different operating systems (*portability*). Further, Daum and Sargent (1999) stated that the system architecture or design should provide the ability of different simulation software to communicate with each other (*interoperability*). This is essential in the recursive hierarchical model composition. Scalability may be achieved through *distributed execution* of the simulation model. The Internet has more potential for collaborative simulation and modelling. It is also possible to have different parts of a model run in different computers linked by the Internet, for example, using Grid computing technology (Ryzerz et al. 2005). Many simulation users are not expert programmers. Therefore, they appreciate the ease of use of simulation software.

Apart from the many advantages of CBS, there are a number of issues that need to be addressed for the successful and widespread adoption of CBS. Robinson et al. (2004) identified that the lack of motivation for model developers was one of the obstacles.

Bass (1969) is a seminal paper that proposes a diffusion model of innovation and new products. The model explains the dynamics of the adoption, using the rate of adoption to define the diffusion of the innovation amongst potential adopters. The marketing literature includes numerous applications of the Bass diffusion model. Previous research has focused on the demand side dynamics of the diffusion and adoption processes. Here we study the adoption and diffusion of CBS using an evolutionary dynamics perspective, taking into account both the demand and supply side interactions and the micro-specificities of behaviour of various stakeholders involved. This paper proposes a business model to show the potential financial benefits of using CBS that would be gained by different stakeholders, including the model developers. We identify four main stakeholders as detailed in the next section.

The rest of this paper is organized as follows. In section 2, we discuss the role and interactions between four main stakeholders. We propose the business model in section 3. We discuss result in section 4. Our concluding remark is in section 5.

2 MAIN STAKEHOLDERS

In any system we need to identify the various agents and how they interact and influence each others' actions. We identify four main stakeholders in a CBS business environment. They are: component users, component providers, certification providers, and indexing service providers. Earlier, Pidd (2002) proposed a simple financial model to model the costs and benefits of component reuse. He further noted that the model assumed all the costs were borne by the one stakeholder, i.e., component providers. We extend his model to study the costs and benefits of CBS from the perspective of the four stakeholders.

In this paper, we assume that a simulation model is made up of a number of components. This can be generalized to any hierarchical composition that allows a model to be formed from sub models and components, or a component to be formed from smaller components. Note that we differentiate between a model and a component. Pidd (2004) defined a model as the representation of the system of interest and is used to investigate possible improvements in the real system or to discover the effect of different policies on that system, while a component is defined as an encapsulated module with a defined interface, providing limited functionality and able to be used within a defined architecture (Pidd 2002).

The process and workings of the business environment modelled in this paper operate under the micro-economic assumptions of perfect competition. There are four main assumptions that are important for the development of our proposed business model. Firstly, we assume that all products sold in the market, in our case components, are identical. An implication of this assumption is that price differences cannot be explained by different product/component attributes. A second assumption is that there is perfect information amongst all agents. For example, all consumers are aware of the market price such that they will not buy from a retailer that is selling a component (identical) above the market price. A firm that sells above the market price will lose market share. A third assumption is that there is no barrier to entry into this industry such that new firms entering the industry get access to the same technology as those who were operating in the market. The final assumption is that any single firm in the market by its own action cannot influence the market price; the firm is therefore a price taker. This means that the firm can only control its output. These assumptions are open to obvious criticisms in that they may be interpreted as being too simplistic and perhaps unrealistic. We do not disagree with this view. However, we need these assumptions for the sake of demonstrating the dynamics of the model and the implications. In fact, it can easily be shown that relaxing some of the assumptions does in fact add some more "realism" but does not in any way affect the dynamics of the model.

2.1 Component Users

In the context of CBS, the customers are the component users (the users, thereafter). The users are organizations, or workers in the organizations, which develop simulation models from various simulation components. They use the simulation models for decision-making. The user has to make the simple decision of whether to develop its own simulation model or to buy the various components in the market to build the simulation model. The only factor that influences this decision to buy components from the market is the financial benefit. We assume here that the firms have the necessary capabilities to develop their own components. The financial benefit comes from the cost saving in the simulation model development (U) as shown in Equation 1.

$$U = D - \left(I + C\right) \tag{1}$$

If the user decides to totally develop the model, then it will cost him/her the development costs (D). Otherwise, if the user decides to buy the components, the cost is the price of the components (C) as well as the integration costs (I) which includes the costs of validating the composed model. Therefore, the saving is obtained from the difference between the costs incurred if the user totally develops the model himself/herself and the costs incurred if the user builds the model from the components he/she buys.

Fowler (2003) argued that the ability of system dynamics to model nonlinearities, inertia, delays, and networked feedback loops in a system made it suitable to model the relationships between organisations and their business environment. In this paper, we also use system dynamics to model the CBS market. Figure 1 shows the demand side of the model using the stock and flow diagram that is commonly used in system dynamics (Sterman 2000).

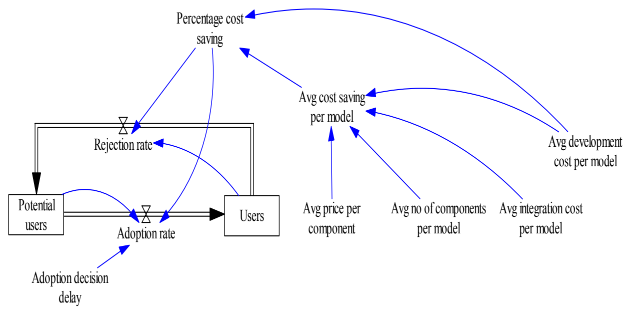

Figure 1: Component Users

2.2 Component Providers

Component providers (CP) are defined here as organizations which develop re-useable components that can be used to build larger components as well as simulation models. The main motivation for a component provider is to make a sustainable profit in the long term. The average component provider's profit (P) can be represented as Equation 2.

$$P = \frac{(N \times C + H - D)}{M} \tag{2}$$

As per our assumptions, there are no barriers to entry in this market. The decision to enter the market will depend on an expected minimum level of profit (P_{min}). Any firm will enter the market as long as it can make at least P_{min}. The total cost can be defined as the total cost of developing the component plus the minimum level of profit P_{min}. This means that the total revenue must cover development cost as well as the minimum level of profit. Firms will be attracted to the market by the fact that established providers are making more than the minimum level of profit. This will be the case in the short run when there are few firms operating. Over time, as the number of provider increases, the market price of the components will fall and all firms will be making the minimum level of profit and there will be no further entry into the market. The total revenue depends on the number of component users who have bought the components (N), the number of component providers (M) and the market price of the components (C). Therefore, the profit is the revenue minus the development costs (D). H is a non-negative number that represents the benefit of using the component for in-house applications. For simplicity, we assume that H is zero.

Figure 2 shows the supply side of the model. The attractiveness is defined based on the CP profit to desired CP profit ratio. The attractiveness is zero and one when the ratio is less than 1 and when the ratio is greater than a constant k, respectively (k represents a value beyond which the market becomes attractive to all potential component providers). In this model, we use a simple linear relation to model the attractiveness between the ratio of one and k.

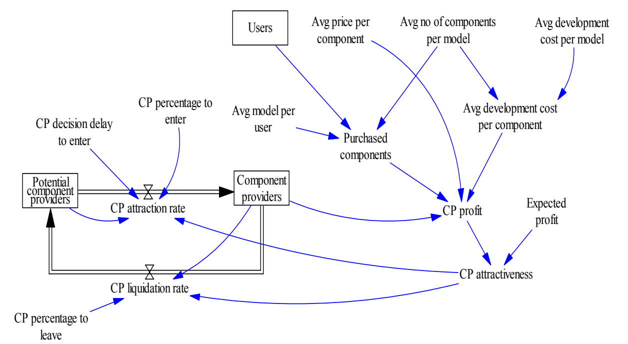

Figure 2: Component Providers

2.3 Certificate Providers

Component reuse is dependent on trust (Pidd 2002, Balci 2001). Imperfect information about different components capabilities and their providers increases the perceived risk of buying components. Hence, there must be institutions or organizations (we call them certificate providers) that can guarantee the validity of the simulation components developed by the component providers. Balci (2001) has long noted the importance of certification providers especially for the establishment of marketplace for CBS. The certificate providers will be present in the market only under imperfect competition. In our perfect competition and information regimes, there is no need to model the action of the certificate providers. If we relax this assumption we can easily incorporate the role of certificate providers in the model.

2.4 Indexing Service Providers

When the number of available differentiated components increases, a search engine for searching and arranging information becomes very important. This is true for any software component (Sommerville 2004). An indexing service provider is an institution or an organization that provides an indexing service so that component users can find the components they need easily and accurately. Again, here in our framework the role of indexing providers is not modelled explicitly since we are operating under a regime of perfect competition and undifferentiated components.

3 BUSINESS SYSTEM DYNAMICS MODEL

Having identified the four stakeholders, in this section, we build an interaction model to show the dynamics of the system. Our main objective here is to explore how we can model the interaction activities of different stakeholders. In

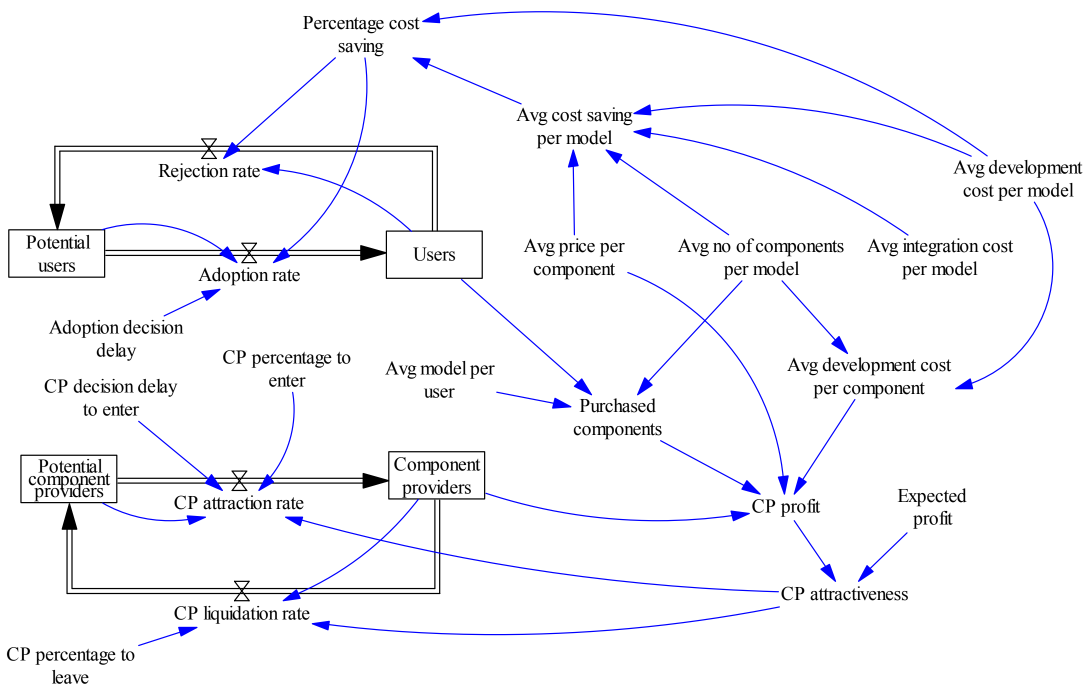

Figure 3: Interaction between Component Users and Component Providers

this paper, we use a simple model describing the interaction between component users and component providers and demonstrate how the market will evolve. Furthermore, we also want to show if it is possible for both stakeholders to gain the financial benefit. This condition is necessary for the growth and long term prospect of the CBS market. The model in Figure 3 shows the early stage of the market.

When the market matures, new component providers will have to offer differentiated components in order to get competitive advantage over existing component providers. This, in turn, would attract certificate providers and the indexing service providers to enter the market as well. We leave the modelling of the certificate providers and the indexing service providers as further research.

4 DISCUSSION

The CBS market is simulated for a period of 10 years using Vensim® from the Ventana Systems which can be used to develop and analyze system dynamics modelling and simulation `<www.vensim.com>`. In the first part, we discuss the demand side of the market. The number of potential users is assumed to be constant at 1m and initially there is no adopter. The delay for a potential user to become an adopter is assumed to be one month Figure 4 shows how the cost saving affects the number of users. The top figure shows that at the lower cost saving, the number of users increases moderately. When the cost saving is increased linearly from year 5 to year 8, the number of users increases exponentially. On the bottom figure, the cost saving is reduced within the same period. The number of users falls sharply. The number of users reaches zero when there is no cost saving. This model shows a non-linear relationship between cost saving and the adoption rate.

In the second part, the supply side of the market is discussed. The number of potential component providers is assumed to be constant at 1,000 and initially there is only one provider in the market. The time for a potential provider to enter the market is assumed to be six months. Initially there is no adopter in the market. The result is shown in Figure 5. The components are priced to give the users 40% cost saving. It is assumed that each user requires one model per year and each model requires a constant number of components. The top figure shows the growth of component provider population with respect to the number of users. The bottom figure shows the movement of the average monthly profit. The number of users increases slowly until it reaches the saturation point. The increase in the number of users brings more profit to the provider. This subsequently attracts a number of potential providers to enter the market which creates tougher competition. The competition reduces the average monthly profit which forces some of the providers to leave the market.

The result shows that it is important to price the components in such way that cost saving should be substantial in order to attract potential customers. The model shows that in the long run, both component users and component providers may gain some financial benefits by adopting the component-based simulation.

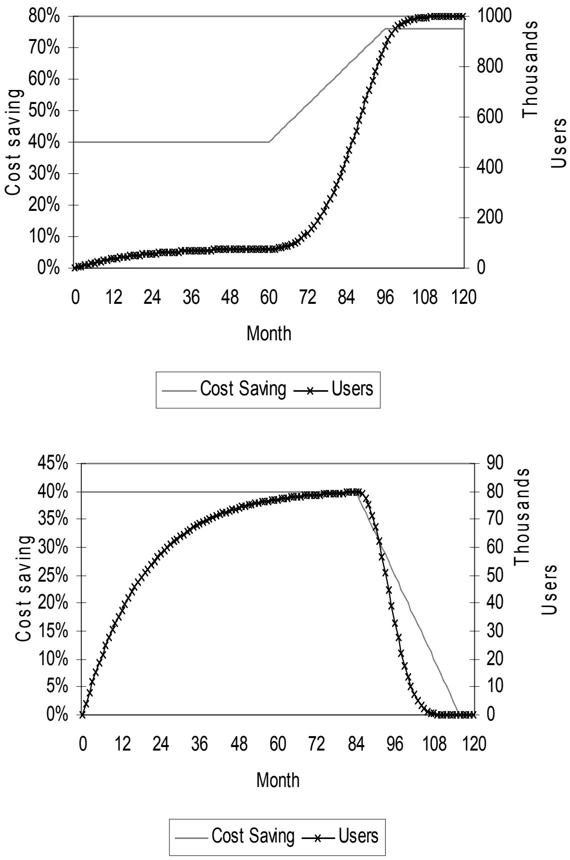

Figure 4: Cost Saving and Component User Population

5 RESEARCH IMPLICATION, CONCLUSION AND FUTURE WORK.

The main contribution of this paper is to propose a business model for the component-based simulation market, modeled via system dynamics. We provide an exploratory framework which demonstrates that both component users and component providers may gain some financial benefits in the long run. This provides the foundation for our future research which will address the following. First, we have to address the heterogeneous characteristics of users. For example, different users will have different motivations and capabilities such that this will influence the decision to adopt CBS. Other factors such as word of mouth and advertisement need to be addressed too. Second, we have to take into account that different components will exist in the same market. Third, different component providers have to be addressed as well. For example, different providers will have different motivations and capabilities to provide new components when they enter the market. Finally, as mentioned previously, we have to extend our work to include the remaining two stakeholders: certificate providers and indexing service providers.

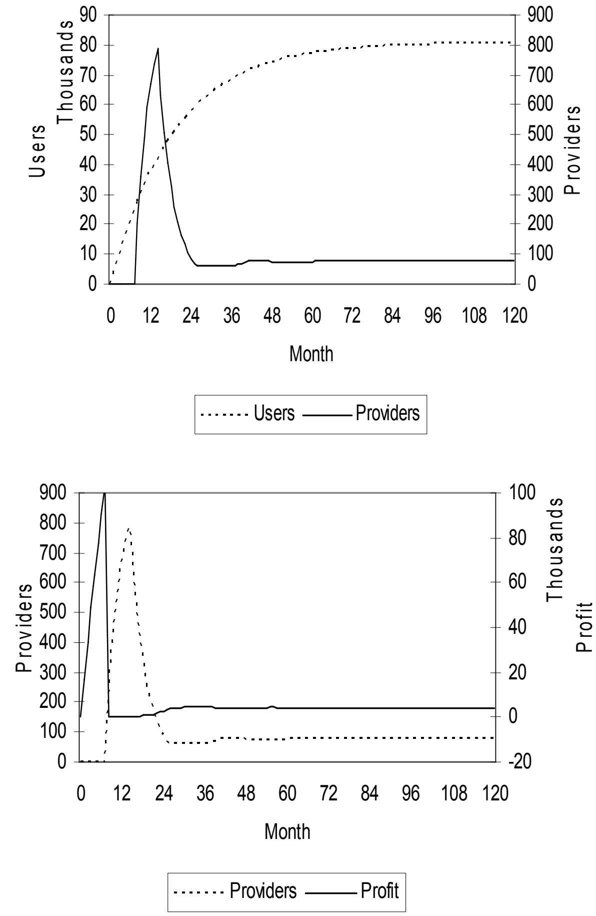

Figure 5: Component Provider Population

REFERENCES

Balci, O. 2001. A Methodology for Certification of Modeling and Simulation Applications. *ACM Transactions on Modeling and Computer Simulation*, 11 (4), pp. 352–377.

Bass, F. 1969. A New Product Growth Model for consumer durables. *Management Sciences*, 15, pp. 215-227.

Daum, T. and R.G. Sargent.1999. Scaling, Hierarchical Modeling, and Reuse in an Object-oriented Modeling and Simulation System. In *Proceedings of the Winter Simulation Conference*, pp 1470-1477.

Fowler, A. 2003. Systems Modelling, Simulation, and the Dynamics of Strategy. *Journal of Business Research* 56, pp. 135–144.

Huang, X. and J.A. Miller. 2001. Building a Web-based Federated Simulation System with Jini and XML. In *Proceedings of the 34th Annual Simulation Symposium*, pp. 143-150.

Jacobson, I., M. Christerson, P. Jonsson, and G. Övergaard. 1992. Object-oriented Software Engineering: A Use Case-driven Approach. Addison-Wesley.

Miller, J.A., Y. Ge, and J. Tao. 1998. Component-based Simulation Environments: JSIM as a Case Study Using Java Beans. In *Proceedings of the Winter Simulation Conference*, pp. 373-38.

Oren, T.I. 1984. Model-based Activities: A Paradigm Shift. Simulation and Model-Based Methodologies: An Integrative View, pp. 3-40.

Oses, N. 2002. Component-based Simulation. PhD Thesis, Lancaster University.

Pidd, M. 2004. Computer Simulation in Management Science, 5th Edition. John Wiley & Sons Ltd.

Pidd, M. 2002. Simulation Software and Model Reuse: A Polemic. In *Proceedings of the Winter Simulation Conference*, 772-775.

Reese, R. and D.L. Wyatt. 1987. Software Reuse and Simulation. In *Proceedings of the Winter Simulation Conference*, 185-192.

Robinson, S., R.E. Nance, R.J. Paul, M. Pidd, and S.J.E. Taylor. 2004. Simulation Model Reuse: Definitions, Benefits and Obstacles. *Simulation Modelling Practice and Theory*, 12, pp. 479-494.

Rycerz K., M. Bubak, M. Malawski, and P. Sloot. 2005. A Framework for HLA-based Interactive Simulation on the Grid. *Simulation*, 81 (1), pp. 67-76.

Sommerville, I. 2004. Software engineering, 7th edition. Pearson Education Limited.

Spiegel, M., P.F. Reynolds Jr, and D.C. Brogan. 2005. A Case Study of Model Context for Simulation Composability and Reusability. In *Proceedings of the Winter Simulation Conference*, pp. 437-444.

Sterman, J.D. 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. Irwin McGraw-Hill.

Verbraeck, A. 2004. Component-based Distributed Simulations: the Way Forward? In *Proceedings of the 18th Workshop on Parallel and Distributed Simulation*, pp. 141-148.

Zeigler, B.P. 1987. Hierarchical, Modular Discrete-event Modelling in An Object-oriented Environment. *Simulation*, 49, pp. 219-230.

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