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Risk Assessment Model for Emergency Departments in Dublin Hospitals

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RISK ASSESSMENT MODEL FOR EMERGENCY DEPARTMENTS IN DUBLIN HOSPITALS

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Abstract

The internal dynamics of emergency departments (ED) in Irish hospitals represent complex non-linear stochastic systems with an environment of uncertainty, variability and limited resources. Planning and managing such systems pose overwhelming demands. To improve operations, patient service, resource planning, and real-time reaction to unexpected events, sophisticated tools to efficiently achieve these goals must be applied.

Advanced solution techniques (e.g. simulation and optimisation) have been successfully applied in manufacturing operations to improve the delivery, cost-effectiveness and service quality. Yet, random arrival of patients, limited resources and multitasking are challenges in EDs that add more complexity to this critical area. This study delivers a contribution to both theory and practice. By the elaboration of patient risks types, simulation is investigated for its compliance with risk management approaches that hence delivered modifications to the simulation modelling approach. This investigation and the modifications allows the conclusion that simulation is suited for risk management and that simulation models are applicable as risk assessment models for healthcare once the modifications are considered by the modeller.

1. Introduction

Demands on the health services continue to grow and increasing health care costs are a reality which the Irish healthcare system is addressed by undergoing rapid change at the present time (Department of Health & Children, 2007). Health care providers and suppliers therefore aim for efficient solutions to continue to provide their services. Hospitals play an important role as a health care provider: medical care, surgical operations, diagnosis, and acute care are the key missions, of which all share common resources like for example diagnosis devices, treatment rooms, and waiting rooms. In order to provide their services as efficiently as possible, it is in the interest of the hospital managers to keep the ratio of uncertain patient arrival to elective patients as low as possible. Hospitals usually operate with a limited number of special skilled resources and activities (e.g., physicians, nurses, and radiology tests). As a result, processes in the hospitals tend to include many of handoffs so that all patients have access to these resources (i.e., the process behaves like an assembly line). These handoffs generate process delays, longer patient cycle time, and higher length of stay (Bale and Krohn, 2000). Most of the time spent in the hospital is non-value added time, such as waiting in queues. This problem can get worse with high arrival rate of patients coming to the emergency department (ED) (Miller et al., 2003).

Highlighting the Irish healthcare problems in the current media reveals long waiting lists and overcrowded Irish EDs that illustrates that the system currently in place cannot meet the demands placed on it (Lynch, 2004). As a solution technique, one might consider capacity management, which considers three factors: how many patients arrive, at what rate, and how long will the service take (Fottler and Ford, 2002)? These factors include a significant degree of uncertainty, which should be kept as low as possible for efficient planning and forecasting. Another source of uncertainty is the change of the distribution of the patient-mix over time. Patient-mix and patient demand is affected by the local placement of the ED and seasonal

changes; for example, a higher patient demand is identified to be related to the cold seasons (Vasilakis and El-Darzi, 2001).

It is therefore obvious, that capacity planning definition is a key element to effectively manage the processes within EDs. Identifying the demand is an essential step to plan the required resources (short-term / long-term) that facilitate thorough utilisation of capacity as well as a smooth interruptionless flow of patients through the system. Errors in forecasting for capacity planning has an immediate impact on the service quality level, for example; considering in planning elderly people – who used to be served before in community service centres – may have to stay overnight in EDs (McDermott et al., 2002).

The potential of simulation to achieve an increase in performance within the available resources is one of its major benefits. In addition, the flexibility to integrate other solution techniques, such as optimisation, artificial intelligence, and data mining, or the capability to consider uncertainty and complexity, enhance the reputation of simulation as a solution finding technique for health care. Due to its flexibility, tools and techniques are already inherited within the simulation framework that would allow the development of risk assessment models for healthcare facilities. Its general applicability is based on the lineup with the new Committee of Sponsoring Organizations of the Treadway Commission (COSO) (2004) framework within this paper. Subsequent a tutorial based on process flow diagrams is presented in order to apply those tools and techniques in that manner that simulation is becoming applicable for risk management on the low level modelling basis.

2. Background

The Irish EDs play an important part in the provision of primary care in Ireland, considering the high self referral rate (Health Service Executive (HSE), 2007b). Access to the service within EDs is congested and the internal processes experience various types of delays: diagnosis not available on time, doctors and nurses busy with other patients, and missing documents (Regan, 2000). Latest statement of a consultant in an Irish ED describes, that the state of Dublin EDs remains severe:

> *"Emergency departments have an extremely important function and compromising the ability of the staff and units to perform it by allowing them to be dangerously overcrowded is potentially life threatening and absolutely unacceptable."* (Gilligan, 2007)
> Dr. Peadar Gilligan, Consultant in Emergency Medicine, Beaumount Hospital, Letter to the Editor, Irish Times, 26 February 2007.

A combination of the three features: high utilisation of resources, long waiting time for service, and diversion of ambulance admission, is the condition to describe the status of an ED as "overcrowding". The mortality rate due to overcrowding in ED can be as high as 30% based on a study of Australian EDs (Richardson, 2006, Sprivulis et al., 2006). According to the findings described above, the EDs in Dublin can be described as overcrowded and health service deliveries are far away from their optimal settings with long patient waiting times and delays for treatment, and a high occupancy level (Health Service Executive (HSE), 2007a).

Considering the increased potential of a rise in mortality due to overcrowding it is essential to look at the safety of the patients to minimise the risks that a patient might encounter. Overcrowding is a phenomenon which is characterised by high utilisation of resources, long waiting time for service, and diversion of ambulance admission. To minimise the risks for patients, and to facilitate the ED with tools to prevent potential threats, a risk assessment model is proposed which utilises simulation modelling technique in combination with business process management and risk management.

3. Literature review

Simulation applications, such as discrete event simulation (DES), have successfully been applied in manufacturing, military and logistic sectors and has proven to have many advantages such as (Pegden et al., 1995):

- Scenario testing without interference of the real system
- Bottleneck analysis
- Capacity planning
- Investigations on certain phenomena
- Investigation of correlations of variables
- Integration of optimisation

To help decision makers in health care facilities, simulation has significantly increased its acceptance among clinicians and hospital managers (Jacobson et al., 2006).

The latest applications of DES to EDs show a high variety of possible application fields, including capacity planning, scheduling of staff and resources, and general conceptual planning for future development of the facility. The following examples are a few of the many applications of simulation studies conducted in health care: one example displays how capacity planning, which calculates the maximum occupancy level of beds, can provide an efficient patient flow (Bagust et al., 1999). To even the peak of resources utilization, the arrival pattern of patients is identified, which allows a significantly better planning of staffing and resources (Sinreich and Marmor, 2005). A similar study enabled a reduction of patient turnaround times (Sinreich and Marmor, 2004). A major benefit of DES is that scenarios can be tested by stating "What-If" questions. In one study scenario testing allowed the development of a new fast track lane within the ED that absorbed a third of all patients (Blake and Carter, 1996). DES also offers interfaces for optimisation techniques, as for example genetic algorithms, that enabled Yeh and Lin (2007) to reduce patient queuing time by an average of 43 per cent.

EDs face the highest degree of uncertainty within the healthcare supply chain. The primary mission of the ED is to provide acute care to patients. A common unique feature of EDs is the extensive use of prioritisation by allocating triage units, which is common and essential to provide immediate care for patients with the most acute conditions (Mackway-Jones et al., 2006a). To guarantee the response to most acute patients, it is necessary to identify the upper limit of the utilisation of resources and staff of the ED in order to provide a reserved capacity for spontaneous increased patient demand. A DES model is used to identify an in-patient bed occupancy level of less than 85 per cent to be the upper limit in order to avoid bed crisis, which is caused due to the lack of capacity reserve (Bagust et al., 1999).

The examples show how healthcare management benefits from the use of simulation, yet simulation models applied so far, focus on optimisation of certain settings or to evaluate certain effects of certain circumstances, replicated by scenarios. However, health care simulation models rarely integrate risk assessment that considers the involved risk of processes of the overall simulated facility. Business organizations have already set an example by applying traditional process management tools with risk management techniques, but as zur Muehlen and Rosemann (2005) indicated that "process and risk management communities are rather separate groups with different research agendas and methodologies"(zur Muehlen et al., 2005, p. 1) which hence shows that there is a need for research in order to merge these methodologies. To address this issue they apply an approach which extends the Event-driven Process Chain techniques with risk awareness, by integrating risks probabilities in the control flow and the control logic diagram. This notation however cannot consider all types of process-related risks, due to its limitation that everything has to be represented by functions.

Another framework proposal focuses on the application of the systems-thinking paradigm (Gharajedaghi, 1999) to the recent COSO framework (2004) that defines enterprise risk management as a process for identifying and managing potential events that incorporates principles and guidelines applicable to avoid negative potential events (O'Donnell, 2005). The systems-thinking paradigm is addressed to the layer of the COSO framework that encompasses the event identification by including value chain maps and associated agents within the systems-thinking paradigm.

In order to consider risk assessment within simulation modelling, its framework is compared with a well established risk management framework proposed by COSO within this paper. This comparison shows that simulation can contribute significantly to risk management by applying its already inherent tools and techniques for statistical analysis and process management. By regarding the new COSO framework one should bear in mind that the framework rather describes guidelines and principles than providing the managers with a strict framework – the intention is to leave the choice to the decision makers which methodology is the best suitable for their business (COSO, 2004). An evaluation of the simulation modelling framework (Banks et al., 2005) against the COSO guidelines shows the suitability of simulation for risk management within this paper.

4. Patient risk types

The healthcare value chain is *full* of potential threats for a patient. Risk awareness therefore is of major concern for Irish EDs. In order to evaluate the risks for each patient a triage method is used which categorizes the patients according to the recommendations of the Manchester Group (Mackway-Jones et al., 2006b). Triaging patients investigates the patients' severity status according to his complaints and assigns them a number which prioritises the urgency of required treatment. Furthermore the patient faces risks by placing himself in the environment of the ED. Generally those environmental risks can be divided into four subcategories within healthcare facilities:

- Internal risks
- External risks
- Direct risks
- Indirect risks

Direct risks are those that affect a patient immediately as an individual, while indirect risks represent potential threats that worsen the condition of the patients without immediate impact, for example long waiting times can cause complications. Internal threats are those that origin from the healthcare facility directly, while external threats are those that affect both, the patient and the healthcare facility like high patient demand, infections brought in by other patients or visitors. Potential threats, or triggered events, can apply to more than just one subcategory, for example, a risk for the patient to be infected by an illness is a direct risk which can also be internal, due to a lack of hygiene standards within the healthcare facility, or external, due to other new incoming patients. The following table 1 gives an example of how these subcategories can be applied to potential threats.

Table 1: Types of patient risks within a healthcare facility.

Triggered event / potential threat	**Direct**	**Indirect**	**External**	**Internal**
Infections	x		x	x

Accidents		x		x
Complications		x		x
Wrong treatment	x			x
Wrong diagnose	x	x		x
High patient demand		x	x	
No resources available	x			x

The triggered events described in the table 1 can widely be covered by rules and regulations implemented by healthcare management in order to avoid these risks and potential threats. Training of staff, to guarantee that the highest hygiene standard is maintained, is one of many measures that management can apply in order to avoid those risks for their patients. Threats associated with occurring events are monitored and analysed by investigating the obtained data of a healthcare facility. Empirical examination of databases in coherence with risk assessment provides necessary data about the frequency of an event that triggered an error or about correlations to other events. Statistical analysis provides information about the event history of a healthcare facility and provides an estimate for future developments which is used by risk and process management. These findings can be used in order to facilitate patient care pathways that encompass techniques from process management. To classify and calculate the potential threats in general, principles are proposed in the COSO framework that provides guidelines for process and risk management.

As described above, simulation is highly regarded in manufacturing as a decision support tool. It flexible approach allows the integration of other solution techniques that incorporate optimisation techniques. Healthcare managers and researchers have already embraced simulation and used it successfully to increase the efficiency and delivery of their service to their patients. However, in terms of risk management in healthcare, simulation yet little contributed to capture the whole range of patient risks within the healthcare facility.

Considering the advantages of simulation, one advantage should be emphasized: forecasts. Statistical analysis of a facility focuses on the past events, whereas simulation can apply recent or even actual data in order to forecast future developments. Hoot et al. (2008) have shown, that reliable forecasts are possible up to eight hours in advance. If such a simulation is implemented to have access the latest patient arrival times, a reliable early risk indicator is applicable, which alerts staff and administrators of potential risks for the patient and proactive measures can be applied.

5. The risk assessment model – an evaluation

In order to demonstrate that simulation is applicable as a risk assessment model for healthcare facilities, a simulation framework is illustrated and integrated into the horizontal layers of the COSO guidelines. The major simulation procedures are listed and explained how they can be inserted in the risk management principles described as:

- Internal environment
- Event identification
- Risk assessment
- Risk response
- Control activities
- Information & communication
- Monitoring

Whereas the major procedures of discrete event simulation modelling are derived from Banks et al. (2005):

- Setting the objectives
- Conceptual modelling
- Data mining
- Simulation modelling
- Simulation test runs
- Validation and verification
- Implementation
- Post project evaluation

To check the compatibility of simulation modelling with risk management, the simulation modelling procedures are checked how they comply with the COSO guidelines. Figure 1 displays a brief summary of how the simulation framework derived from Banks et al.(2005) is similar to the COSO framework. Considering the original COSO guidelines, one might argue that the achievement of objectives (strategic, operations, reporting, and compliance) and the application level (entity-level, division, business unit and subsidiary) are not considered. But, as those elements are valid for discrete event simulation, only the main procedural process flow is illustrated and compared for clarity reasons.

Analogue to risk management *objectives* are defined at the start of a simulation modelling project. *Objectives* are the key element to each project, where the risk manager defines the target area of the investigation and its application, whereas the simulation modeller agrees with the stakeholder about the scope of the project and his deliveries. Both abstract the reality in a brief reflection in order to focus on the essential elements of the project as well as on the primary issues and problems.

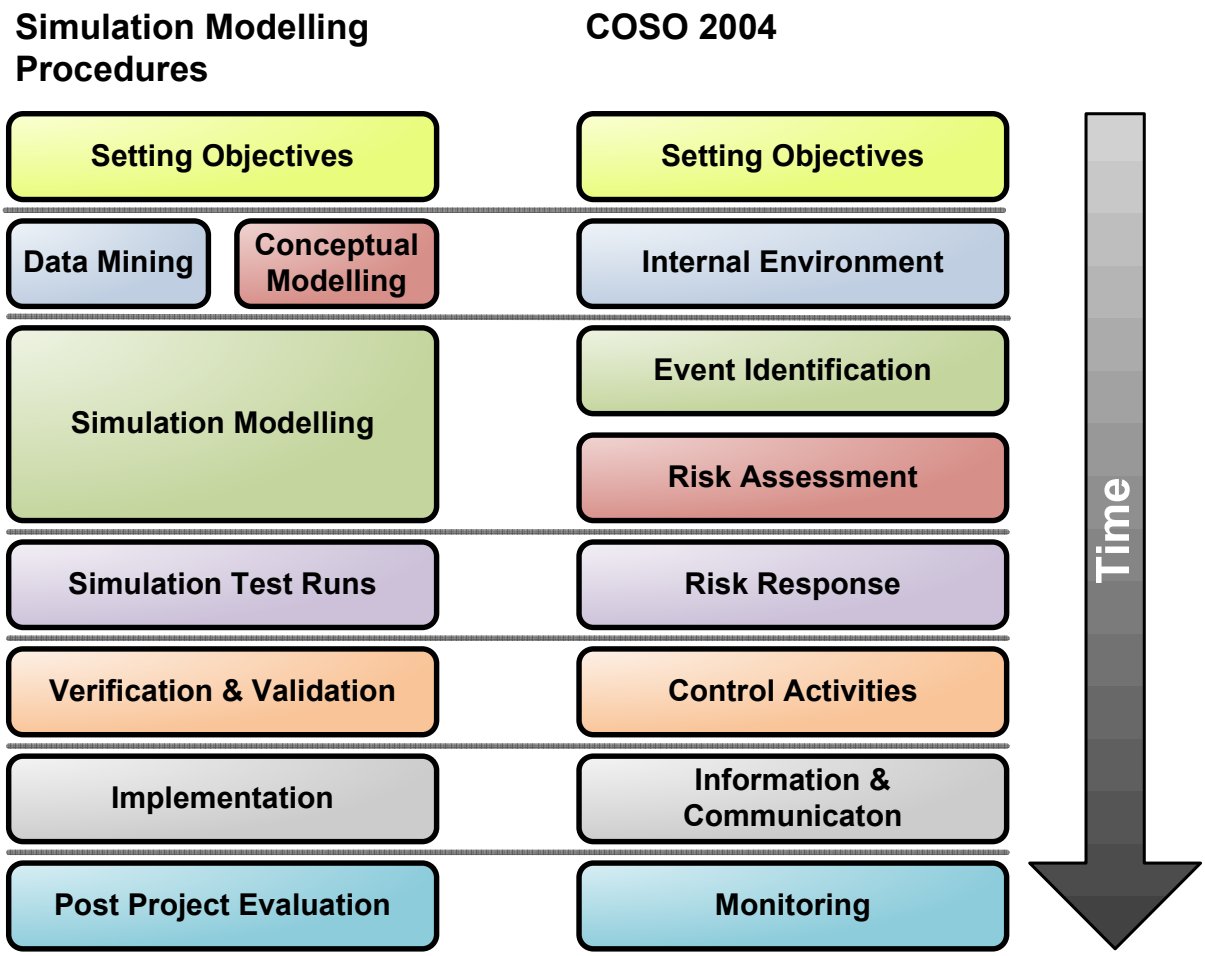


Figure 1: A comparison of the procedures of the discrete event simulation (derived from Banks et al., 2005) with the COSO guideline (Committee of Sponsoring Organizations of the Treadway Commission (COSO), 2004).

Conceptual modelling maps the process flow as a general network representation triggered by events and items travelling through the system. The simulation modeller uses conceptual modelling techniques that are well established, such as UML, IDEF, Petri nets (PN), coloured Petri nets (CPN), business process maps, or flow charts. The modeller evaluates which techniques suites best for the system under investigation. The necessary data to build a representational conceptual model is acquired by data mining techniques that differentiate between quantitative and qualitative data retrieval. Both, quantitative and qualitative data is merged in the conceptual model that reflects the events that interact with the flow of the items. This procedure is similar to the *internal environment* investigation that identifies the

events that trigger or influence a certain risk to a process or individual. The simulation modeller and the risk manager make use of conceptual modelling techniques, whereas the risk manager would use additional techniques derived from Business Process Management (zur Muehlen and Indulska, 2009), such as Simple Rule Markup Language (SRML) or Production Rule Representation (PRR).

Data mining is the crucial element of simulation modelling which is essential to build a representative simulation model of the real system. Data can be either retrieved qualitatively, by interviewing involved staff or by observing the processes, and / or quantitatively by analysing the available process data stored in databases. Conceptual modelling techniques help to illustrate the results of the analysed and retrieved data which hence further helps to investigate the real system. However, the amount of obtained data can be overwhelming and thus it is essential to agree on the level of detail, which describes the simulation model. This abstraction is essential in order to focus on those elements that have an impact for the system – details without an impact only cause an unnecessary distraction and confusion for the modeller and the user of the simulation model. Those elements that have an impact for the model are events or activities displayed as processes within the process map in a conceptual manner. Data mining as a part of the data retrieval process is required for the *Event Identification* and for the *Risk Assessment* within the COSO guidelines. The evaluation of risks according to the corresponding events is depending on a sound analysis of data.

The process of modelling the *simulation modelling* channels the previous procedures in order to develop an executable simulation application that represents the real system as closely as intended within the set objectives. The simulation model is based on the conceptual model

and on the retrieved data from the data mining process. The model considers the patient arrival times, the processes mapped within the conceptual models, and the process data obtained by the data analysis. Additionally the identified risks associated to a process or event can be considered by declaring a risk attribute for each item. This will be elaborated in the later section 6 which describes how to apply risk assessment to a simulation model. A timeframe is set which simulates the activities for each item and generates an output assembly which is used to verify the simulation model with the real system. *Validation* however ensures that the simulation model is a valid representation to the real system during the transformation of the conceptual model into a simulation model.

Simulation test runs is essential to identify errors occurring due to the implementation of the model in a simulation environment. Logic errors or runtime errors are intended to be erased. This step is an ongoing sequence accompanying the modelling and the verification and validation procedures and enriches the understanding of the system and identifies potential improvement suggestions. This procedure also involves the identification and evaluation of *risk response strategies* that indicate ways to avoid, accept, reduce, or share risks for potential threats or errors within the system. These avoidance strategies may imply changes to the actual simulation model. At this point it might be worthwhile to consider these changes in a set of scenarios in order evaluate the impact of the avoidance strategies.

Once final adjustments are applied to the simulation model, a final *verification and validation* defines the precision of the simulation model. Precision is expressed as a statistical value in a confidence interval which gives a definition of how valid and applicable the model is to solve the identified issues and problems. After having defined the validity of the model and

evaluated the impact of risk avoidance strategies, *control activities* are derived from the findings of the impact analysis. Those control activities describe policies and procedures which potentially minimize risks. These control activities have to be tailored in a way that they are ready for implementation and that they consider the staff, their working environment and the actual patient.

Depending on the objectives, the simulation model is used for several purposes and experiments:

- Risk assessment
- Optimisation
- Scenario testing
- Resource allocation
- Capacity and demand forecasting

The results obtained from the above experiments are evaluated by its costs and benefits, which has a direct influence of the consideration for its *implementation*. Each change to a system inherits a potential risk. These risks have to be considered and to be included in the potential occurring costs. The better the data base on which the simulation model is built, the easier the implementation risks can be evaluated. Once a change to the system is identified to be beneficial, these changes have to be communicated and illustrated to staffs that are affected by the change. This procedure is similar to the second lowest COSO layer describing *information and communication* of the results obtained by the risk management. In either case, whether COSO guidelines or simulation modelling, implementation of the results may require training and commitment of staff in order to get the findings and objectives applied to the actual system.

Post project evaluation of the implemented results derived from the simulation model allows a target/actual comparison, where the calculated benefits are confronted with the actual benefits, thus allowing a final measurement of the effectiveness of the simulation modelling. Another post project procedure is the *monitoring* of the implemented changes, especially those concerning the risk avoidance strategies. Here it is essential that the anticipated risk avoiding effects ensure a successful implementation, otherwise modifications might be necessary.

6. Development of a risk assessment model within discrete event simulation

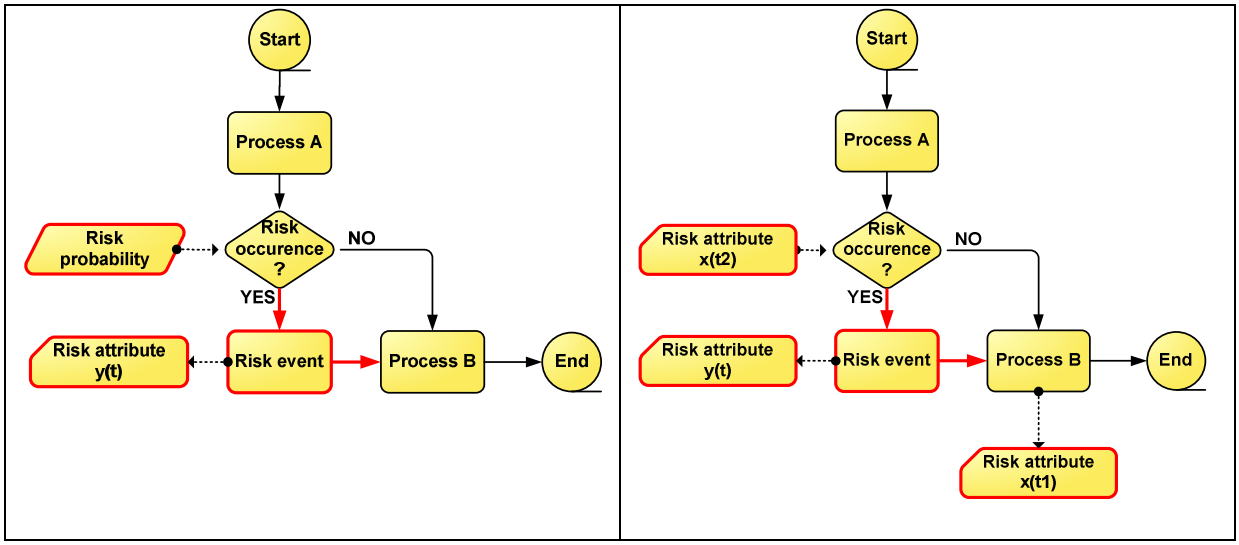
Overall both frameworks, the simulation modelling and the risk management framework proposed by COSO show similar approaches, and display a significant overlap which indicates a potential for synergy effects. In fact, when applying simulation modelling, the management might consider analysing the risks involved within the analysed system, or vice versa, risk management might be interested in simulating the applied changes in order to identify its impact. However, discrete event simulation requires some adjustments to fully comply as a tool for risk management. Fortunately the simulation approach already delivers everything that is required for risk management, for example simulation packages integrate statistical tools that provide the input data, or the activities, with a certain set of statistical distributions. Another useful feature is that items include attributes that are modifiable. Those two features are required in order emulate the four above described potential risk types for the patient: for direct and internal risks, that are likely to occur, activities have to be inserted in the route of the patient which is triggered by a random generator. The source for

these risks are identifiable and assignable within the healthcare facility, thus a *risk process* is sufficient for these types of threats. The probability of the occurrence of a risk is then stored within the *risk attribute* and will be accumulated with all the other risks that a patient might encounter through his journey of the healthcare facility. Indirect and external risks require *risk attributes* as the source of the potential dangers is not directly assignable. The probability value is altered by the indirect threats that may be a certain value influenced by other parameters. For example the queuing time for treatment influences the probability of complications by a certain value or function. Table 2 indicates how the risk types can be considered in simulation modelling.

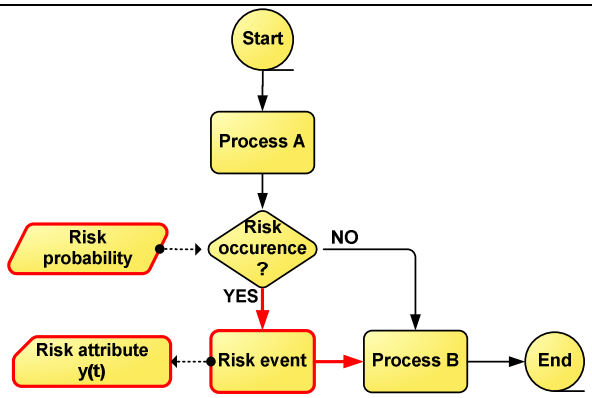
To explain the handling of the risk types, process flow charts are applied, to deliver the concept of risk application within simulation modelling on the modelling basis. The red frames indicate the entities that involve risk. Four different risk entities are used: a *risk probability*, that can be any random number generator; a *risk event*, that represents the additional workload associated to the risk; a *risk attribute x(t),* that contains the accumulated probability that faces a patient; and *risk attribute y(t)* which is a list of Boolean variables that records the event history.

Table 2: Modelling techniques for discrete event simulation in order to comply with risk management.

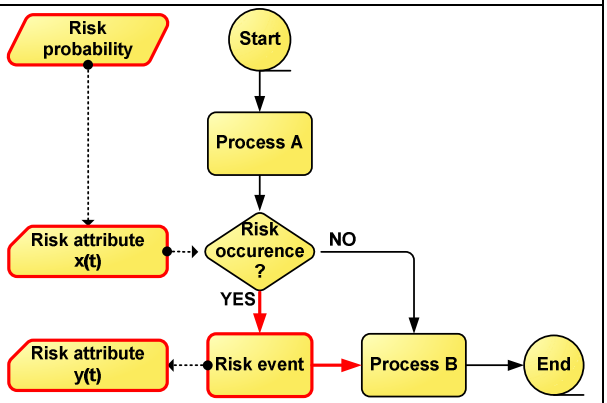
Direct risk	**Indirect risk**



Internal risk



External risk



In the case of direct risks, for example, an occurring accident underlies a certain probability. In the upper left example of table 2 the patient enters the system by being processed in the process A. In case the *risk probability* inflicts an event, the patient gets diverted and the consequences of this event have to be faced. This event will store its value (Boolean) in the *risk attribute y(t)*, which stores this event in an event history for later risk analysis. The upper right example of table 2 displays the handling of indirect risks. The patient enters the system as in the upper left example, whereas the process B has a high potential of queuing up the system, which influences the risk for complications for the patient. The *risk attribute* is set at the time *t1* while the patient is still in process A. After leaving the process A the patient

attributes triggers the likelihood of complications at time *t2*. In case complications occur, the event is again stored in the attribute value *y(t)* for later examinations.

The handling of the internal risk is similar to the handling of the direct risks. The external risk is illustrated by an influence of a *risk probability* that affects the *risk attribute x(t)* directly. This influence can hence either be handled similar to the direct or the indirect risk handling.

Applying this technique allows the modeller to obtain the associated risks directly from each individual, and if necessary already at runtime. Additionally an event history delivers insight about the likelihood of the occurrence of events that are connected to risks of which impact can be evaluated with the overall outcome of the simulation run.

These changes require little modification of the traditional simulation modelling procedure, but hence it equips the modeller with the feature that each patient gets a risk value assigned during his journey through the simulated system. After being released from the healthcare facility the simulated patients delivers a risk history and a probability, lets say a risk value, which illustrates how likely those risks occurred. This risk value stays with the patient whatever sophisticated route the patient is taking through the complex healthcare system. As healthcare facilities and their patient pathways tend to be highly sophisticated this technique easily captures all potential types of risks occurring to a patient and presents a useful illustration of the sources and of the accumulating effect of risks for a patient.

7. Discussion

Irish healthcare is currently in a severe condition: long waiting times, high demand, budget cuts, are just few of the concerning terms addressed in the daily media. In fact, healthcare managers are striving for efficient solutions. Considering the threat of the increased mortality which is linked to overcrowding (Richardson, 2006), efforts have to be done rather sooner than later. However urgent improvements are needed, the according investments have to be placed efficiently especially during recession when governmental funding for healthcare is low. Comparing the waiting times for treatment which were about 6.5 hours in Dublin EDs in 1999 (Regan, 2000), they only declined little to 5.2 hours in 2007 (based on findings of the analysed academic teaching hospital under investigation with ca. 45,000 patients treated annually). It can be seen that improvements aligned with the investments done over eight years had no tangible improvement for the average patient. It is therefore crucial to identify the impact of investments in advance. As pointed out in the introduction, simulation is a promising approach to evaluate measures to increase the quality of care.

In accordance to the necessary improvements of the quality of care, strategies for risk avoidance is essential that comply with well established risk management techniques applied in business process management. The COSO framework delivers a sound basis for risk management, but the integration of process management is still an area for research (zur Muehlen et al., 2005). Efforts are made to integrate business process management strategies into risk management, such as system thinking paradigm (O'Donnell, 2005) or process flow techniques (zur Muehlen et al., 2005).

Healthcare managers however have established patient care pathways in order to integrate process flow and risk management. Care pathways allow identifying the involved treatment processes that a patient group requires, mapped for further use. Statistical data of patients that followed this pathway gives an insight for improvement potential. Many countries have already introduced care pathways in their hospitals, but after years of the introduction critique arises: care pathways are not flexible enough due to its complexity which makes it hard to alter, when improvements or adjustments are required (Dy et al., 2005) and due to the limited display opportunities of the diagrams additional substantial comments are required, which makes it difficult to interpret for outsiders and inflict another potential error source (Molle, 2009). These are the main critiques, which may be a cause why the Irish healthcare managers are reluctant to integrate care pathways.

Considering the effort to apply risk management and process management in healthcare, an integrated comprehensive solution is desirable, that is in compliance with established approaches. In this paper it is discussed how the simulation modelling process can be altered to comply with the proposed framework for risk management by COSO. It is shown that only minor adjustments and considerations to the modelling techniques are required as all necessary tools are already inherit in the simulation approach. Integrating risks into the process flow offers many advantages:

- Focus on the patient and the accompanying risks
- Integrated solution, that is compliant with established management approaches
- Traceability of risks increases system transparency
- Forecasts are possible with actual patient data
- Simulation well established as an flexible approach

With these benefits the healthcare managers gain immediate control and additional transparent insight into the risk event history and the potential threats to each patient. As simulation would be an integrated solution, it offers a win-win opportunity:

- first, the simulation model allows analysing the system similar to the mapping of patients care pathways,
- second, simulation offers the integration of solution finding techniques such as optimisation, scheduling, etc.,
- third, risk assessment is already integrated within the simulation study which hence has the potential to improve the quality of care,
- fourth simulation is flexible enough to allow modifications and adjustments.

These advantages however face a major drawback: developing or adjusting a simulation application is a time consuming process – especially building a simulation model that has to represent a sophisticated and complex structure such as they are found in healthcare domains, demands a lot of effort of the modeller. It can be argued that time is already saved due to the fact that simulation can be used equivalent to patient care pathways during the process analysis and process mapping of a healthcare facility. But to access the above listed advantages simulation requires a tailored framework that allows an easy adjustable routing, consideration of the here addressed risk assessment techniques, and a free and easy scale ability of the employed models. Such a framework is of current research within the 3S-Groups established by the Dublin Institute of Technology. Overcoming these drawbacks would enable simulation to be an invaluable comprehensive tool for healthcare facilities.

8. **Conclusion**

Healthcare in Ireland requires urgent help. Long waiting times, overcrowded EDs, high utilisation of staff and resources indicate that there is need for an effective change within the healthcare facilities. To allocate the highest potential impact of investments a sophisticated and comprehensive solution technique is required that would be able to cover complexity, uncertainty and system dynamics. Simulation has shown to be a successful tool for manufacturing and healthcare. Its recommended improvements derived from the simulation approach had significant impact and increased the quality of care in countless examples (Jun et al., 1999, Cayirli and Veral, 2003, Eldabi et al., 2007, Fone et al., 2003, Jia et al., 2007).

Simulation has therefore illustrated to be a valuable approach in order to improve process flows within healthcare, but is it the end of the rope for simulation? Has it shown all of its potential, yet? As illustrated within this paper it can be seen that the flexible approach of simulation allows to be adjusted for risk management. The overlaps of the simulation modelling procedures with the COSO framework are obviously an indicator for its applicability for risk management. The illustrated modifications, or lets say considerations that a simulation modeller would have to include, are of minor effort and enhances simulation to serve in several fields with one answer. Considering the suggested approach within this paper would comprehend process management, risk management and include the benefits of simulation in one comprehensive approach. However, two significant drawbacks have two be considered: first, building a simulation model of a complex and sophisticated system requires a considerable amount of effort, and second, the more complex the model, the more difficult is its maintenance.

Complexity issues require a new approach or even a new framework, which would enable simulation to be well suited in complex and sophisticated domains, such as healthcare. This issue is of current research of the 3S-Group established by the Dublin Institute of Technology in collaboration with Dublin academic teaching hospitals to enable Irish hospitals to apply the newest and most comprehensive solution finding techniques for their concern and problems.

References

BAGUST, A., PLACE, M. & POSNETT, J. W. (1999) Dynamics of bed use in accommodating emergency admissions: stochastic simulation model. *BMJ,* 319**,** 155-158.

BALE, J. & KROHN, R. (2000) Redesigning Under-Performing Physician Organizations. *http://www.healthsystemsdirect.com/article8.html, accessed 10/11/2008.* GROUP PRACTICE JOURNAL.

BANKS, J., CARSON II, J. S., NELSON, B. L. & NICOL, D. M. (2005) *Discrete-Event System Simulation,* London, Pearson Prentice Hall.

BLAKE, J. T. & CARTER, M. W. (1996) An analysis of emergency room wait time issues via computer simulation. *INFOR,* 34**,** 263–273.

CAYIRLI, T. & VERAL, E. (2003) Outpatient scheduling in health care: a review of literature. *Production and Operations Management,* 12**,** 519–549.

COMMITTEE OF SPONSORING ORGANIZATIONS OF THE TREADWAY COMMISSION (COSO) (2004) *Enterprise risk management — integrated framework.,* Jersey City, NJ, American Institute of Certified Public Accountants.

DEPARTMENT OF HEALTH & CHILDREN (2007) Health in Ireland - Key Trends 2007. Government of Ireland.

DY, S. M., GARG, P., NYBERG, D., DAWSON, P. B., PRONOVOST, P. J., MORLOCK, L., RUBIN, H. & WU, A. W. (2005) Critical Pathway Effectiveness: Assessing the Impact of Patient, Hospital Care, and Pathway Characteristics Using Qualitative Comparative Analysis. *Health Services Research,* 40**,** 499-516.

ELDABI, T., PAUL, R. J. & YOUNG, T. (2007) Simulation modelling in healthcare: reviewing legacies and investigating futures. *Journal of the Operational Research Society,* 58**,** 262-270.

FONE, D., HOLLINGHURST, S., TEMPLE, M., ROUND, A., LESTER, N., WEIGHTMAN, A., ROBERTS, K., COYLE, E., BEVAN, G. & PALMER, S. (2003) Systematic review of the use and value of computer simulation modelling in population health and health care delivery. *Journal of Public Health,* 25**,** 325.

FOTTLER, M. D. & FORD, R. C. (2002) Managing patient waits in hospital emergency departments. *Health Care Manager,* 21**,** 46–61.

GHARAJEDAGHI, J. (1999) *Systems thinking: managing chaos and complexity — a platform for designing business architecture,* Boston, MA, Butterworth Heinemann.

GILLIGAN, P. (2007) Ahern on Beaumont's 'bad day'. *Irish Times, February 26, 2007.*

HEALTH SERVICE EXECUTIVE (HSE) (2007a) Emergency Department Task Force Report. http://www.hse.ie/en/Publications/HSEPublicationsNew/AcuteHospitalReportsGuidelines/EDTaskForceReport/#d.en.7030.

HEALTH SERVICE EXECUTIVE (HSE) (2007b) Emergency Departments - Patient Profiles, Experiences and Perceptions. *http://www.hse.ie/en/Publications/HSEEmergencyDepartmentsPatientProfilesExperi/FiletoUpload,4586,en.pdf, accessed 20/03/07.*

HOOT, N. R., LEBLANC, L. J., JONES, I., LEVIN, S. R., ZHOU, C., GADD, C. S. & ARONSKY, D. (2008) Forecasting Emergency Department Crowding: A Discrete Event Simulation. *Annals of Emergency Medicine,* 52**,** 116-125.

JACOBSON, S., HALL, S. & SWISHER, J. (2006) Discrete-Event Simulation of Health Care Systems. IN HALL, R. (Ed.) *Patient Flow: Reducing Delay in Healthcare Delivery.* Springer.

JIA, H., ORDÓÑEZ, F. & DESSOUKY, M. (2007) A modeling framework for facility location of medical services for large-scale emergencies. *IIE Transactions,* 39**,** 41 - 55.

JUN, J. B., JACOBSON, S. H. & SWISHER, J. R. (1999) Application of discrete-event simulation in health care clinics: A survey. *Journal of the Operational Research Society,* 50**,** 109-123.

LYNCH, P. (2004) 89% of voters would prefer GP-based A&E service. *Irish Medical News.*

MACKWAY-JONES, K., MARSDEN, J. & WINDLE, J. (2006a) *Emergency Triage,* Oxford, Blackwell Publishing.

MACKWAY-JONES, K., MARSDEN, J. & WINDLE, J. (2006b) *Emergency Triage: Manchester Triage Group,* Oxford, BMJ.

MCDERMOTT, R., CALLANAN, I. & BUTTIMER, A. (2002) Involving Irish clinicians in hospital management roles - towards a functional integration model. *Clinician in Management,* 11**,** 37-46.

MILLER, M. J., FERRIN, D. M. & SZYMANSKI, J. M. (2003) Simulating six sigma improvement ideas for a hospital emergency department. IN FERRIN, D., MORRICE, D. J., SANCHEZ, P. J. & CHICK, S. (Eds.) *Proceedings of the 2003 Winter Simulation Conference.*

MOLLE, R. (2009) Modellierung Klinischer Behandlungspfade (German) - Modelling care pathways. IN HTTP://WWW.BPM-NETZWERK.DE/CONTENT/ARTICLES/VIEWARTICLE.DO?ID=D915570D1EE529A1011F03E9E6F42397&SOURCE=4&QUERY=MOLLER (Ed.) *BPM-Netzwerk.de.*

O'DONNELL, E. (2005) Enterprise risk management: A systems-thinking framework for the event identification phase. *International Journal of Accounting Information Systems,* 6**,** 177-195.

PEGDEN, C. D., SHANNON, R. E. & SADOWSKI, R. P. (1995) *Introduction to Simulation Using SIMAN,* New York, McGraw-Hill.

REGAN, G. (2000) Making a difference to A&E: analysis of the operational inefficiencies in A&E departments in major acute hospitals in Dublin. *Accident and Emergency Nursing,* 8**,** 54-61.

RICHARDSON, D. B. (2006) Increase in patient mortality at 10 days associated with emergency department overcrowding. *Medical Journal of Australia,* 184**,** 213-216.

SINREICH, D. & MARMOR, Y. (2004) Emergency departments' operations: a simple and intuitive simulation tool based on the generic process approach. *unpublished paper http://iew3.technion.ac.il/Home/Users/sinr/emergency2.pdf,[accessed December, 03, 2007]*.

SINREICH, D. & MARMOR, Y. N. (2005) Emergency Departments Operations: The Basis for Developing a Simulation Tool. *IIE Transactions,* 37**,** 233-245.

SPRIVULIS, P. C., DA SILVA, J., JACOBS, I. G., FRAZER, A. R. L. & JELINEK, G. A. (2006) The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *Medical Journal of Australia,* 184**,** 208-212.

VASILAKIS, C. & EL-DARZI, E. (2001) A simulation study of the winter bed crisis. *Health Care Management Science,* 4**,** 31-36.

YEH, J.-Y. & LIN, W.-S. (2007) Using simulation technique and genetic algorithm to improve the quality care of a hospital emergency department. *Expert Systems with Applications,* 32**,** 1073-1083.

ZUR MUEHLEN, M. & INDULSKA, M. (2009) Modeling languages for business processes and business rules: A representational analysis. *Information Systems,* doi:10.1016/j.is.2009.02.006.

ZUR MUEHLEN, M., ROSEMANN, M. & BRISBANE, Q. (2005) Integrating risks in business process models. *16th Australian Conference on Information Systems.* Sydney.