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IMPLEMENTATION ISSUES OF MODELING HEALTHCARE PROBLEMS: MISCONCEPTIONS AND LESSONS

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ABSTRACT

Since the beginning of the 21st century, the role of modeling and simulation in healthcare domain has seen unprecedented attention from the academic community. So much literature has focused on barriers facing implementation and uptake of modeling and simulation by the healthcare community. This article focuses on this issue and goes beyond that and examines the nature of healthcare problems and the causes of barriers using the concept of wicked problems. There is a clear mismatch between the wicked nature of healthcare problems and the tame approaches proposed by the modeling community. The article concludes that with the existence of such mismatch, implementation cannot be used to measure success, and further suggests guiding principles when developing modeling and simulation approaches to tackle wicked healthcare problems. These are based around redefining the meaning of success, problem profiling, modeling methods, and modeling skills.

1 INTRODUCTION

RIGHT Research Into Global Healthcare Technologies `<www.right.org.uk>` is a UK based collaborative research project aiming to identify and motivate a wider use of modeling and simulation within healthcare sector. The project fulfilled its first phase (feasibility study) by carrying out a number of *literature reviews* to map out existing knowledge, empirically evaluate receptiveness of users community through a number of *exemplars*, and by developing a *toolkit* framework for selecting the most suitable method for the right problem. A number of useful lessons have been generated from each of the three streams of work. For example, in terms of the literature review, three of the reviews conducted were looking at the prevalence of the nature of use of modeling and simulation in healthcare, defense/aerospace, and industry/business, respectively. When conducting the review analysis we have classified outcomes into three classes: *Class A* - a real problem and real stakeholders. *Class B* - real-life problems, no engagement from real stakeholders. *Class C* – theoretical propositions and enhancements. Figure 1 presents a normalized representation of the results regarding the above classes within each of the three domains. From the figure it can be seen that 8% of Healthcare publications were Class A, Defense/Aerospace and Industry/Business had 36.5% and 48.9% respectively. This shows a significant difference between the healthcare domain and the other two domains, which resonates with findings from Fone et al. (2003) and Taylor et al. (2009). Clearly this suggests that there are some barriers for what can be termed as "simulation success" within healthcare domain, particularly that modeling in this field has started since the early beginnings of the other two domains.

Regarding the exemplars, another set of lessons were generated, not so much in how to conduct modeling but also in how to engage with stakeholders. Some of these methods laid out in Brailsford et al. (2009a). Moreover, many of the barriers deduced from the literature reviews were highlighted by the exemplars. For example, the difficulty of keeping stakeholders on board all the time, lack of understanding of the problem is a common issue, the use of relevant terminology, and a myriad of other lessons that will feature in this article where relevant. In general, there is a clear disparity between users' expectations and modelers' views of modeling. As for the toolkit framework, it has been refined through a number of iterations with potential users to reach its current form (www.right-toolkit.org.uk). Although the toolkit was built for the purpose of selecting suitable methods to be used for modeling, the most important lesson obtained was that users have indicated that the framework was useful in allowing them to reflect on the nature of their problem. It was evident that there was a need to focus on the initial work of profiling the problem.

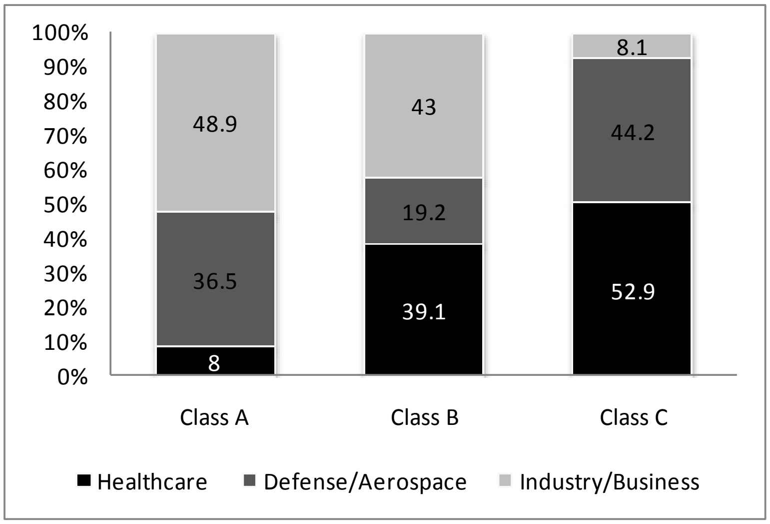

Figure 1: Distribution of levels of stakeholders by domain

Coming towards the end of its feasibility stage the RIGHT project has found that there is an overwhelming demand for modeling and simulation tools in the healthcare community, whilst there is a sizeable body of knowledge amongst the modeling community, yet there is a clear gap between what is needed and what is on offer. Bridging such a gap between the two communities will require a great deal of effort in trying to identify main linkages and successfully setting them up. For this purpose the RIGHT project has selected for its next phase a number of issues to be tackled, namely, stakeholders issues, methods suitability, data issues, and the wider context of healthcare.

This article is one of three articles in the 2009 Winter Simulation Conference, which are further analyzing and reflecting on these issues and presenting some future directions to initiate the debate within the wider modeling community. The other two articles are focused on stakeholders issues and grand challenges in the area. The particular focus of this article is the general profile of healthcare problems and the way modelers approach them, whilst doing that the article will discuss the meaning of success and implementation of modeling healthcare problems and provide some guidelines aiming at improving modeling effectiveness and, hence, uptake by the healthcare community. In doing so, the article will draw from lessons generated from the first phase of the RIGHT project and the literature overall. The article starts by reviewing existing barriers to implementation as suggested by the wider literature. Then the article will briefly discuss some theories of profiling problems – mainly the concept of wicked problems – and their characteristics. Such characteristics are then used to inform the general profiling of healthcare problems. Following that there will be a discussion about ways to tackle different types of problems and to what extent this may or may not work for healthcare problems. The article will finish by drawing all of these issues together into a set of guiding principles for approaching healthcare problems based on problem profiling, guidance for method development, and skills needed by modelers.

2 BACKGROUND TO BARRIERS

The discussion about barriers to implementation – or merely completing the cycle – of modeling and simulation projects in healthcare is a long standing one and continues to be even more topical. In fact the existence to such barriers was one of the main reasons for embarking on the RIGHT project. One of the early discussions about barriers was a panel in the 1994 Winter Simulation Conference (Hakes et al. 1994). The panel came up with a number of barriers such as: lack of clear incentives for healthcare managers who relied mainly on simpler and deterministic analytic techniques; resistance to the unfamiliar; the dehumanizing nature of simulation; eagerness of modelers to overcomplicate their models; and the competing priorities and variations of customers. Another couple of barriers added by Lowery (1996), are the perception by clients that modeling takes longer than the problem requires and also their perception that modeling is yet another layer of commitments on top their normally busy schedule. Harper and Pitt (2004) point out a set of challenges to modeling and implementation that include: the complexity and multiple interactions associated with healthcare systems; fast changing national policies; the level of buy-in from the community; and lack of reliable data. Brailsford (2005) stresses the previous set of barriers and add a new set including: the intrinsic culture of lack of trusts of industrially based methods; the cost of modeling; the poor data available or its messiness; the clash of interests between modelers and problem owners; and the lack of uniformity amongst healthcare systems. The aforementioned barriers and a multitude of others, either cited in the literature or from a personal experience, can be categorized into three main classes of barriers: conflicting interests, lack of relevant tools and the mismatch of expectations between users and modelers. These are detailed below:

Conflicting interests of stakeholders: almost all publications in the field have stressed the fact that healthcare systems suffer from multiple ownership and complex decision making process. For a modeling exercise seeking a unified goal this is usually quite difficult (if not impossible) to attain. In fact it is sometimes the case that even one user might change their views along the modeling project. If all or some of the stakeholders (particularly key decision makers) do not have any interest on the model, then regardless of the result such a model is doomed to failure.

Lack of relevant tools: healthcare domain has borrowed most of its modeling tools from other domains such as manufacturing. These do not usually lend themselves so readily to capture the essence of healthcare systems. Over the years there have been numerous attempts such as Paul and Kuljis (1995) and Harper (2002). Although these tools have provided the look and feel that are relevant to healthcare, still they were based on engines developed with other systems in mind. Sometimes a simple requirement such as modeling co-morbidity pathways – a situation that is quite routine in healthcare – could take a long time to incorporate in the model, leading to disappointment by healthcare stakeholders.

Mismatching expectations: a number of healthcare professionals do not usually have a good idea of what modeling is or which type to select for which problem. Some are looking for a solution by a press of a button. If stakeholders think that the modeling will take longer than required, then it will not be commissioned. Similarly, modelers usually fail to use the right jargon or provide a better explanation of the benefits of the model. Whilst some other modelers have the believe that they should end up with an all encompassing answer. Many modelers blame the system for lacking relevant data that can be used for modeling.

Stakeholders involvement, which is captured in more detailed in Brailsford et al (2009a), is an important element in problem solving and modelers need to bear that in mind. A number of articles have called for the importance of that with some methods/guidelines to support stakeholders engagement (Eldabi et al. 2002; Robinson 2001). It must be stressed that the above barriers are not necessarily restricted to healthcare, in fact other domains suffer from some of these issues albeit with a lesser effect. For example (Robinson and Pidd 1998) recognize expectation management as a major success factor for any simulation project regardless of the domain. Academic culture is partly to blame for exhibiting such low engagement portfolio, as most published literature tend to toy with the rigor of their techniques without giving much attention to their respective practicalities. Gass (1996) provides thoughtful analytical narratives on the tendency to publish thoroughly theoretical models with less implementation value. For this reason it is not clear whether authors focus on theoretical issues because of the lack of interest by stakeholders or because of the nature of the discipline. As shown in Figure 1, 59.9% of publications in healthcare were on hypothetical problems using hypothetical data, this is a clear indication to the abundance theory in healthcare modeling, yet not much conversion to practice.

3 THE WICKED NATURE OF HEALTHCARE PROBLEMS

Most of the barriers and challenges to healthcare have focused on stakeholders, tools, and complexity. These barriers may be central to the nature healthcare systems, or maybe they appear as a result of the way modelers approach such problems. the fact of the matter, not many are able to identify the root causes behind such barriers. Even if we know the causes, currently there are no specific means to tackle them. For this reason we look back at the history of problem definitions and ways to classify the different types of problems. In this article we particularly look at the concepts of wicked and tame problems, where healthcare problems fit. The seminal paper by Rittel and Webber (1973) have produced the concept of "wicked problems" usually defined as problems that are impossible to solve (not evil as the name might suggest), while denoting other types of problems as "tame". The main characteristics of wicked problems are listed below (Rittel and Webber 1973):

- There is no definite formulation of a wicked problem.
- Wicked problems have no stopping rules.
- Solutions to wicked problems are not true-or-false, but better or worse.
- There is no immediate and no ultimate test of a solution to a wicked problem.
- Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
- Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
- Every wicked problem is essentially unique.
- Every wicked problem can be considered to be a symptom of another wicked problem.
- The causes of a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
- With wicked problems, the planner has no right to be wrong

Pidd (2007) summarizes the above characteristics into three major ones: *clashing objectives*, *shortage of data*, and *multiple stake-holders* who have very different opinions from stake-holders on what is desirable. A whole discipline (problem structuring methods - PSM) was established, with so many approaches and methods following it (Pidd 2007; Rosenhead 1996). The aim of any PSM is mainly to move the problem from a mess to a problem that has one or more known solutions. Such a concept is well reported, and many methods were proposed, however, given the "soft" nature of such methods, it was very difficult to evaluate which one is the best.

3.1 Are Healthcare Problems Wicked Problems?

In the first instance it is not reasonable to assume that all healthcare problems are wicked problems. However, one cannot ignore the fact that the set of barriers, mentioned in Section Two, is an exact match to the characteristics of wicked problems, particularly those summarized by Pidd (2007). Usually a wicked problem is a large scale phenomena. From a healthcare policy perspective such a match is quite obvious, for example, deciding upon the best cancer screening policy could prove to be a wicked problem – given the complexity and the multitude of stakeholders associated with such policy. So it is possible to assume that most of the healthcare policy and strategic issues are messy (or wicked problems) and they should always be approached as such. On the other hand, one might expect that smaller scale problems in healthcare not to be wicked as such. However, the opposite is more prevalent and this what differentiates between healthcare systems and other sectors. One of the biggest challenges that face operational problems solvers in healthcare is defining the boundaries of the problem and the boundaries of influence of the stakeholders. Issues such as redesigning an Accidence and Emergency department or designing a hip replacement unit may seem as a " tame" problem or even a "puzzle" in case of developing a roster. Nevertheless, this is not necessarily the case, usually as a small change to such services could have larger unplanned impacts on other aspects, causing them to expand beyond first thought. It is almost certainly that each problem in healthcare system will feature at least one of the characteristics of a mess.

This shows that most of the barriers mentioned in the previous section arise from the wicked nature of healthcare problems. Healthcare problems do not just exhibit characteristics of wicked problems, they also add a couple of characteristics that are largely related to healthcare systems. Healthcare problems continuously feature changing behavior. Such *changing nature* may be due to national policies or in response to local needs. The change does not only cover the building blocks of the system but could also change in the stakeholders and their relation to the problem and/or the model. A subsequent issue to that is the *time-span* needed to solve the problem. Usually the time needed from inception of the problem to solving it is too short for comprehensive modeling approaches. Some of these problems could only take three months before they are evolved into different shapes.

The author would like to reiterate that this is not a blanket definition for healthcare problems nor there are no methods to deal with healthcare problems. However, and to a large extent, the lack of appreciation to the fact that healthcare problems are always complex and may not be solved using current methods, is probably the most important cause of the barriers mentioned earlier in this article. These barriers are the very characteristics of wicked healthcare problems. To overcome these barriers modelers need to move away from finding methods to remove them to changing the approach we take when solving healthcare problems. Instead of using traditional linear methods we need to find better means to cope with wicked problems.

4 TAME APPROACHES VERSUS WICKED PROBLEMS

As noted in the previous section that almost all healthcare problems are wicked problems (if not, then they are wicked puzzles). One important outcome from this discussion is that the main cause of lack of implementation or lack of prevalence of modeling in healthcare – as that of industry and military sectors – is because most people attempt to solve wicked problem using tame approaches. This is doomed to failure. The following quotation is the abstract given by Rittel and Webber (1973) which is a fitting explanation why tame approaches fail in solving healthcare problems:

"The search for scientific bases for confronting problems of social policy is bound to fail, because of the nature of these problems. They are "wicked" problems, whereas science has developed to deal with "tame" problems. Policy problems cannot be definitively described. Moreover, in a pluralistic society there is nothing like the undisputable public good; there is no objective definition of equity; policies that respond to social problems cannot be meaningfully correct or false; and it makes no sense to talk about "optimal solutions" to social problems unless severe qualifications are imposed first. Even worse, there are no "solutions" in the sense of definitive and objective answers."

Source: Rittel and Webber (1973).

The above abstract indicates that wicked problems do not lend themselves so easily to linear solutions. Scientific methods (or linear solutions) have expected outcomes at the end of the well defined process. None of these work with wicked problems. Most of the existing literature in modeling and simulation in healthcare approach each modeling venture as an exercise that has to have an answer in the end, and most papers write about what the model can do. Currently, most solutions suggested in the healthcare modeling and simulation literature tend to include elements such as: prescriptions of single solutions; back office calculations; lack of transparency; and lack of interactions with and between stakeholders. These are some of the exiting habits which are not necessarily relevant to healthcare problems. In fact each of the current methods focus on the rigor of outcomes rather than a solution to the problem. When it comes to approaching wicked problems we need to think about a resolution rather than a solution and a consensus rather than optimization.

It should be stressed that some literature calls for using PSMs as good candidates for taming wicked problems. However, most authors seem to fall into the linearity trap assuming PSM as the first step of a linear process of problem solving, whilst in reality, healthcare problems seem to switch between wicked to tame status iteratively. The reader is reminded that not all healthcare problems are wicked, for instance, Royston (2009) presents a number of real examples where OR was successfully utilized to solve specific healthcare systems. There is so much literature of methods and specific (tame) contexts where modeling and simulation could be used. However, the issue is not how to solve these problem, the issue is to know which problem needs solution and solution is Pidd and Robinson (2007 provide a spectrum of problem contexts and approaches of modeling used. Pidd (2007) attempts to link between soft and hard methods, mostly relating soft methods to wicked problems and hard methods to tame problems whilst gradually moving from unstructured to structured approaches (i.e. soft to hard). Periyakoil (2007) further stresses the concept of wicked problems in healthcare and that using classical linear approaches will not work. The author here goes on by advocating an iterative rapid approach (PDSA) as an incremental approach to taming wicked healthcare problems.

From the above discussion, it is clear that dealing with wicked problems, people should not be too determined to achieve their planned solution. Lowery (1996) suggests that when tackling healthcare problems people need to keep nibbling on until a satisfactory resolution is reached. Yet, and to complicate matters further, healthcare systems do not have the luxury to wait until a satisfactory resolution is reached. Life needs to move on in healthcare, patients still need to receive care, whilst problems expand very quickly. Also cost is a major issue. Most healthcare institutions will not be prepared to pay problems solvers vast amount of money for prolonged periods of time until such a resolution is reached. The problem has to be resolved within the specified deadline and within the allocated budget, regardless of whether a solution is reached or not. Many have suggested the need to have a set of in-house modeling skills to reduce the financial burden of modeling. The counter-argument for that, regardless of the problem, the solution will always be restricted to the expertise within the in-house skills. Another issue is that most of the proposed means for taming wicked problems do not have specific how-to guidance, some of these largely depend on the skills the modelers have other than those related to modeling. It can be concluded that, in general, healthcare problems are difficult to tame, and if they can be tamed, there is not enough time or money to continue until the problem is tamed.

5 PROPOSED GUIDELINES FOR TAMING HEALTHCARE PROBLEMS

The above discussion seems to be drawing a gloomy picture in trying to tame healthcare problems. This might be the case if we continue to use tame approaches to healthcare problems, or if we apply the proposed taming approaches as they are, whilst expecting a delimited exercise with a *successful* answer in the end. We also saw that trial-and-error approaches do not work, because there is no room for error. Incremental approaches might work, yet the time-span and cost constraints usually hinder such approaches. This might be the case for tame problems as well, that even if we have the right solution for the right problem, costs, time and other constraints associated with healthcare systems may prevent success. Having said that, we learn from healthcare that life has to move on and solutions are bound to provide positive contributions to improve the system. This section outlines two issues with the aim of helping healthcare modelers to tackle some of the challenges illustrated in this article. Firstly, we will look at the way we approach success. Currently we define success by completing a typical simulation project. Secondly, the approach to modeling itself, and what ingredient it needs to have for improving their ability to tame wicked problems.

5.1 What is Success in Healthcare Modeling

It is not reasonable to expect any tame approach to result in implementation in healthcare problems, hence direct implementation cannot be the indication for success when dealing with wicked problems. Perhaps healthcare modelers need to start identifying different values of their models, other than providing good and implementable recommendations. For example, providing a tool for debate amongst stakeholders, providing better insights about the nature of interactions within the system, visual representation of the system, or as a reflective tools. Hodges (1991) lays out six uses of bad model, i.e. models that have not been validated or utilized properly, these uses are: a) as bookkeeping devices; b) as automatic management systems; c) as debating vehicles; d) as stimuli to intuition; e) as idea selling aids; and f) as training aids. Modelers need to be able to let go and depart from the thinking that model's value is the final results. These may be the least useful part, as people reach the final stage they may figured out the problem already.

The first step for pursuing a non-linear solution approach for modeling is for modelers (and stakeholders) to appreciate that there other values to modeling. More importantly is to find ways to identify these values throughout the modeling exercise. One of the exemplars of the RIGHT project intended to develop a model for planning the best patients pathway to meet a certain government targets. Without collecting any data, a very crude model enabled the stakeholders to draw a focus on what they can do in reality and identifying the root causes of their problem. This ceased the modeling effort. Taking a linear approach, this is a disappointing result as the modeling was cut short, yet the overall outcome is a success.

Evidently, departure from such scientific way of thinking is difficult. Linear problem solving is entrenched within both modeling and healthcare cultures. Modelers usually become too attached to their models that it becomes difficult for them to forgo their models for the general interest of problem solving. On the other hand, healthcare professionals seem to be more fixated with the gold standard of modeling and whether it gives the right answer by merely pressing a button. These are challenges that need to be tackled which will be discussed below, in addition to ideas about modeling methods and tools that should be useful.

5.2 Proposed Principles

The above subsection discussed that in order to establish appropriate taming practices, modelers need to change their views about what is meant by success out of their models. This subsection discusses three elements as part of an approach to look at modeling when considering healthcare systems. The three elements are: identifying a wicked problem, methods and tools for healthcare modeling, and modeling skills. These are should not be taken as strict guidance, rather they are points arising from the discussion we had in this paper in terms of the wicked nature of healthcare problems and the different coping strategies suggested earlier.

5.2.1 Identifying a Wicked Problem in Healthcare

Table 1 provides a set of criteria to enable modelers to differentiate between wicked problems and tame problems. These criteria are mainly based on the characteristics suggested by Rittel and Webber (1973) in addition to criteria which are specific to healthcare problems. These were added to reflect some of the complexities associated with healthcare such as time and money. The main aim of the table is to remind modelers to think about the existence of wicked problems before embarking on any modeling.

Table 1: Proposed Wicked versus Tame Problems Criteria

Criteria	**Wicked Problem**	**Tame Problem**
Stakeholders	Multiple with multiple opinions	Single or multiple with a single voice
Problem formulation	There is no definite formulation of a wicked problem.	There is agreed way to formulate each type.
Stopping rules	No stopping rules.	Stops once the solution is reached.
Nature of expected solution	No judgmental solutions, not true-or-false, but better or worse.	Judgmental solutions can be used.
Solution assessment	Solutions cannot be tested. No agreed success criteria.	Solutions can be assessed against set criteria.
Replication of contexts	Contexts can be reset. Each attempt will take the problem to a different direction	It is possible to replicate the situation and assess different strategies
Solution space	There is no specific solution space. There is no set of permissible operations that may be incorporated into the plan.	Usually come with a finite solution space where options can be selected.
Uniqueness of the situation	Every wicked problem is essentially unique.	Tame problems tend to be the same regardless.
Clarity of symptoms and causes	Wicked problems may turn out to be symptoms other [wicked] problems.	It is easy to go to the roots of the problem.
Problem description	Wicked problems can be explained in nu-	Tame problems tend to have exact de-

	merous ways. The choice of explanation determines the nature of the problem's resolution.	scription. The nature of the problem/solution does not depend on explanation.
Circle of Influence	Circle of influence is beyond stakeholders.	Stakeholders can make or influence decisions.
Budget/time/data (mainly healthcare)	Cannot be planned or there is no time and/or budget to reach the solution.	There is enough time and money to solve the problems.

5.2.2 Taming Modeling Methods and Tools

Brailsford et al (2009b) outlined a list of methods that has been used for healthcare modeling and simulation. Most of these methods were originally borrowed from other sectors. This was one of the barriers for capturing the full extent of healthcare systems. They may be useful for tackling tame problems, however, when it comes to wicked problems these methods either fall apart or produce inherently complex models that they negate the basic idea of modeling. Healthcare systems bear some similarities to other businesses, yet they do have specific characteristics that make them different from other systems. This makes it important to develop methods and tools that are capable of meeting these characteristics. Richy (2005) summarizes the main principles that should be followed when developing or evaluating taming method used for wicked problems as proposed by Rosenhead (1996). These are given in the list below:

- accommodate multiple alternative perspectives rather than prescribe single solutions
- function through group interaction and iteration rather than back office calculations
- generate ownership of the problem formulation through transparency
- facilitate a graphical (visual) representation for the systematic, group exploration of a solution space
- focus on relationships between discrete alternatives rather than continuous variables
- concentrate on possibility rather than probability

5.2.3 Modeling Skills

It is very clear that when dealing with wicked problems, modelers need to have other skills in addition to mere model building skills. For example, they need to be able to deal with stakeholder and their differences. They also need to use modeling to compensate for missing facts. They also need to forgo the model when it is time to do so. Pidd (1999) provides five principles of modeling that any modelers need to learn before starting any modeling exercise. On the other hand, Powell (1995) presents six modeling heuristics as the basis for a modeling course. Although these two authors were not necessarily focusing on healthcare modeling and simulation, their issues inspire a vital set of skills needed by modelers in healthcare. Both authors emphasize that as modeling is an art as much as a science. Most simulation curricula currently cover the technical skills such as how to build a model and how to validate it. However, and despite many calls to introduce other soft skills, not much is delivered as part of a formal modeling course. For modeling healthcare problems, the technical ability is only a small part of the expertise needed. One of the exemplars of the RIGHT project was looking at developing a strategy within a local county for a newly rolled out intermediate care (interface between healthcare and social care). The modeling was conducted by a small consultancy company over a period of four months. The effort to build a consensus and shared views about the objectives of the program was about 75%, whilst the effort to build the model itself was 20% or less. much of the consensus building was based on facilitation and ability to manage the differences and powers within and between the different groups. Both Powell (1995) and Pidd (1999) have stressed the need be able to pay more attention to the problem and the stakeholders with less attention to the rigor of the model itself. Overall, modelers need to have the following abilities:

- *Technical modeling skills*: surely each modeler must have some technical skills that enable them to build models. What is important is to able to construct models that contain the relevant building blocks and provide answers to the main questions posed by the stakeholders. It is imperative to be able to also build the relevant visuals and output presentations.
- *Facilitation skills*: modelers need to be able to let the stakeholders express exactly what they think their problem is. Also they need to be able to build a consensus between differing groups and views. Modelers need to be able to avoid expressing their views or impose directions or outcomes.
- *Eliciting information by all means*: modelers need to be able to identify any potential sources of information from the expert opinion of stakeholders to categorized data. This also means the lack of any source of information should not be seen as a constraint, rather as an opportunity to find an innovative alternative.

- *Identifying modeling values*: modelers should be able to identify and spot any interim outcomes that are beneficial to solving the problem. Sometimes the solution may arise from the initial discussion about the model. Whilst some ideas may be triggered as a result of earlier phases of modeling, stakeholders and modelers seldom realize that. Modelers need to have the skill to be able to spot such values and to convey those to stakeholders
- Communication skills: modeler need to be able to have good communication skills to be able to extract the most important element of the problem to be modeled and to be able to keep the stakeholders interested in the modeling. On top of that modelers need to keep communicating with stakeholder throughout the modeling process in order to assess stakeholders' views about the progress of modeling.
- *Ability manage stakeholders*: most wicked problems have multiple stakeholders. Modelers need to be able to manage their interests and differences and the politics behind that. They need to be able the spot the power ranking in terms of making decision and which group will be in charge of implementation. In the end if none of these is happy with the outcomes of the modeling then it will not be implemented.

6 CONCLUSIONS

This article has started with the implicit assumption that implementation of modeling outcomes and recommendations is the main indication of success and, hence, generating more uptake by the healthcare community. We have discussed the fact that healthcare problems are wicked, unless otherwise specified. We also found out that linear (or tame) approaches are not necessarily the best way to tackle healthcare problems. Therefore implementation of modeling outcomes can never a measure of success for modeling. Appreciating the fact that moving from linear scientific approaches to taming approaches is a massive paradigm shift, the RIGHT project has opted for four research streams towards that direction. Specifically, the next phase of the RIGHT project is to investigate how communities of practice within healthcare perceive modeling and their needs, how to improve analytical methods to cope with deficiency of data, how methods can be developed to better suite healthcare, and how the overall healthcare environment could be influenced by from modeling and simulation.

In this article, we have also identified that tame approaches cannot work for wicked problems, therefore three guiding principles were proposed that need to be considered when developing a taming mechanism, namely: problem profiling, methods and tools, and modeling skills. These are all issues related to earlier barriers and taming strategies suggested in previous literature. The final message from this article is that modeling and simulation in healthcare need to give more attention to the wicked nature of healthcare problems. Moreover, many authors have proposed a plethora of taming approaches, yet more focus should be on ways to covert such theories into practice, this has not been given enough attention so far.

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