An Essay on the Economic Outcome of Medical Simulation Education:
How to Think and Evaluate

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Abstract
While many previous works regarding the outcome of medical simulation asserted that high-fidelity, low injury simulation education induces desirable consequence in terms of improving clinical skills and resource management, no fewer works reported, on the other hand, that there are no significant differences between the use of high cost simulators and low cost ones. This implies that the cost-effectiveness of simulation education should be understood not as a problem of simple comparison of technique, but as an economic problem of Return on Investment (ROI). This essay addresses how to identify and evaluate the economic outcome of simulation education/training, from the ROI perspective, in order to confirm the utility and contribution of simulation technology on the progress of medical treatment and health policy stability. A simple model of ROI, as well as a brief explanation of the concept of benefit generation will be introduced after a confirmation of the importance of outcome evaluation in simulation education. Then, as an example, a scenario-based evaluation of the benefits of employing medical simulation for healthcare providers’ networks was conducted. As a result, we conclude that, in order to improve the quality and safety of medical care, the use of simulation education as a quasi-public good is the clearest and easiest way of achieving this goal.

Introduction
Previous works on evaluating outcomes of medical simulation education have been used mainly to evaluate i) the learning effects of instituting simulation based medical education (SBME) into the curriculum in medical schools, ii) improvement in the clinical residents’ skills after receiving training, iii) the consequence of team building in the ER and anesthesiology departments, iv) the effect of error reduction generated at the time of operation, and v) development and introduction of new devices or programs adopted to the demand of trainees and trainers. While the first to third issues have been reporting positive effects or consequences concerning educational outcomes from using
high-fidelity simulation training, the last issue has contributed to the simplification and popularization of simulation training by replacing high-cost simulators with low-cost ones. Further, the forth issue reported clinicians’ real feelings for the avoidance of risky situations in medical treatment without data based evidence.

On the other hand, many works have also been paying great attention to the cost-effectiveness of SBME. Because simulators are so expensive, it would have a huge impact on the management of simulation training by clarifying the economic outcome. This is especially crucial because we are now in an era of finding the most efficient way of administering health care. No fewer works, however, have reported that “there are no significant differences between the effects of training using high cost simulators and low cost ones!” (see Salkini MW. et al. (2010), William M. et al. (2010), etc).

How do we identify the real effects or outcomes of simulation education from an economic perspective? Could we obtain some fresh inspiration by employing improved analytical technologies? I believe, as a health economist, that SBME has economic value as a quasi-public good (Yasukawa (2009)(2011)), and think that the economic outcome of SBME should be understood not as a problem of simple comparison of educational techniques among two groups, but as a macro economic problem of Return on Investment (ROI).

In order to confirm the means and value of the economic outcome of simulation, this essay address the issues of i) the definition of the economic outcome of simulation, ii) the process and method of evaluating the economic outcome defined in advance, iii) the socio-economic requirement at the time of the outcome evaluation, with a simple numeric example.

1. Economic Outcome of Simulation Education
1-1. Why is the Evaluation of Economic Outcome Difficult?

There are three reasons why the evaluation of economic outcome is difficult. First, there is no agreeable standard regarding the end result when trying to evaluate economic outcome. Second, there is no rule for expansion and limitation when deciding the target of the evaluation. Finally, we cannot define the magnitude of the so-called spread effect when trying to calculate the impact of one economic effect on the other. As to the first reason, we can consider that a quick response to the training will be required when basic skills are provided to novice clinicians, while fundamental change of mind and consciousness in more experienced clinicians will be expected when they tend to establish safer medical environment. The timing of evaluating the economic outcome
should vary depending on the kind of training and target assumed. As to the second reason, while the introduction of high-fidelity simulators may induce an economic or managerial outcome for the university or hospital by economizing on education time or through reduction of physicians’ duty as instructors, physicians and nurses who have received high level clinical and decision making skills through high level training may also provide more effective or sophisticated health services. This, in turn, may secure the optimal and sustainable social health system. This macro-economic perspective to evaluate the outcome of SBME should consider broader economic impacts that influence, for example, other facilities or residents in that region. And as to the third reason, we need to predict the magnitude of spread effect in advance. Since, needless to say, spread effect may follow a complicated pathway, magnitude and speed of the spread will depend on the nature and ability of the economic body as well as the relationship between society and individuals.

1-2. Economic Outcome of Simulation as ROI

The important key concept for every outcome evaluation is the fact that the costs for carrying out the SBME are all identified as investments directly tied to the outcomes from that education. Therefore, the returns generated from the investment should be directly related to the evaluation. In actual cases of evaluations, however, the problem of setting targets and considering spread effects would also be very critical.

The simplest ROI model in economic theory is presented below.

\[
ROI = \frac{\text{profit}}{\text{total investment}} \times 100
\]

Where profit is equal the revenue minus costs, then determining revenue, costs and total costs should be required when we want to calculate ROI. In cases of simulation education, only the total investments; the price of simulators, the wage or salary of staff working at SSC (Skills Simulation Center) or lab, can be documented. Both the revenue and costs would be identified as the tuition for each student and the salary of the instructor including opportunity costs of absent instructor from clinical treatment. If the training requires clinicians outside the hospital to have SSC, then the revenue could be viewed as the economic value of marginal benefit generated through the educated clinician’s treatment, the costs as the payroll of instructors in which the loss due to the enormous time consuming by instruction plus the opportunity costs in abandonment of trainees’ clinical commitment. In the last sentence, we need to recognize that the outcome of physician’s medical practice would be affected not only by his/her improved technique as a result of the training, but also by the increased ability and capacity of
other medical resources such as nursing, medical equipment and patients’ cognitions. That is, we describe,

**The outcome of an educated clinicians’ performance**

= (marginal improvement of technique, improvement of other professions’ techniques, patients’ confidence and other environmental conditions)

Of course, we need to understand that both the improvement in other professions’ techniques and patients’ confidence should have a strong relationship to those in the educated physicians’ technique in practice.

When we use cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA), the costs will be assessed in terms of direct and indirect costs which were invested in the practice in question. On the other hand, benefit/effectiveness will be evaluated in the form of direct and observable advantages. In other words, although the costs would be applied to the same measurement in evaluation, the indirect effect on the outcome would be ignored. Indirect effects include both psychological and technological environment. Further we need to consider the derivative of demand for the other socio-medical resources along with the improvement of the physicians’ technique. For example, higher skilled physicians may demand higher skilled nurses when they undertake acute treatment, and vice versa. This situation is named “spread effects” or “repercussion effects” in economic terminology. This is where some quality or ability in one thing may affect the demand for other things (there is no singular for “goods”). Thus the magnitude of economic spread effects is identified by the magnitude of demand for other goods derived along with the process of original goods production.

2. **The Spread Effect Model in Medical Simulation Education**

We will examine two of the steps in order to model the spread effect generated in simulation education. In the first step, we will model the effects in accordance with the different targets in education separately. And then, in the second step, we will estimate the magnitude of modeled spread effects by looking at the relationship between supply and demand among economic units.

a. **Identification of Target and Modeling of the Spread Process**

   The target of simulation education will be divided into three groups: i) students in medical schools, ii) clinicians working at a hospital or university possessing SSC or skills lab, and iii) other clinicians working in the community or region (Yasukawa (2009)). In the case of medical students, educational spread effect may be limited to
the effects on learning at the next stage. For example, when they learn basic anatomy in the first year via a computer based simulator, they can understand more clearly than by traditional textbook study. But this does not increase or decrease the demand for healthcare in the society or the deregulation of the health care system. Thus the spread effect in the education of medical students is “compact” even though the learning is evident.

On the other hand, in the case of clinicians working at a hospital or university possessing SSC or skills lab, there are similar effects as above, improvement of the quality of treatment and clinical decision making as well as team building and clinical efficiency will be expected. If there is a regional network established among medical facilities and clinicians in the community, such effects may generate the cost efficiency within that community through the transition of the quality of clinical skills embodied in trained human resources into those who do not so. Finally, when those who are working in the community are educated through SBME, they then would take on more important roles even if they had never done them before. This means there will be a greater demand for highly skilled clinicians from other economic units in community health care, and this demand may require further supply of health resources in the establishment of, for example, an emergency care system.

b. Estimation of Spread Effects

In the second step, estimating spread effects, we seek to identify demand and economic value, that is, for whom the returns of the spread effects should be designed.

In order to estimate the magnitude of the spread effects from an economic perspective, we usually use an analytical technique named “Input-Output Analysis (IOA)” proposed by Wassily Leontief. Because the IOA was originally applied to the estimation of input and output situations among plural industries at a national level, it does not fit a micro analysis that focuses narrowly on the health care industry. Recently, a more flexible estimation tool for adopting micro level analysis called “Benefit Incidence Table Approach (BITA)” was proposed, in which we can calculate the impact of a socio-economic project from the economic activity of households and firms, i.e. stakeholders, through the application of IOA. The most important feature of BITA is its concept of the “general equilibrium model”. In this model, when each stakeholder seeks their most optimal behavior in the market, demand and supply associated with capturing utility and revenue for all players in that market will be generated simultaneously. This economic process will lead all of them to the social condition of equilibrium. When we tend to estimate the magnitude of spread effects on
this economic mechanism, we might obtain some numeric indices with respect to the social demand for the clinicians; who received appropriate simulation education and, then, the holistic mindset in satisfaction or safety of healthcare. A rough outline of spread effect in simulation context is described in figure 1 and 2. Table 1 shows an example of a typical IOA matrix.

Figure1. A Typical Process of Spread Effect

Figure2. Assumable Process of Spread Effect in Simulation Context
Table 1. Typical IOA Matrix in General Analysis

<table>
<thead>
<tr>
<th></th>
<th>Industry A</th>
<th>Industry B</th>
<th>Final Demand</th>
<th>Domestic Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry A</td>
<td>(x_{11})</td>
<td>(x_{12})</td>
<td>(F_1)</td>
<td>(X_1)</td>
</tr>
<tr>
<td>Industry B</td>
<td>(x_{21})</td>
<td>(x_{22})</td>
<td>(F_2)</td>
<td>(X_2)</td>
</tr>
<tr>
<td>Gross Value Added</td>
<td>(V_1)</td>
<td>(V_2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic Products</td>
<td>(X_1)</td>
<td>(X_2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

demand-supply balancing \(X_{11} + x_{12} + F_1 = X_1\)  
cost-revenue balancing \(x_{21} + x_{22} + F_2 = X_2\)

3. Model Specification of ROI for Adopting Medical Simulation Context

Next, we need to adjust the content of these economic models presented above to the evaluation of economic outcome of simulation education in a real situation, we need to simplify and alter them in order to arrive at the return of simulation investment intuitively.

In the model specification process, we must consider i) the method needed to present the impact of technical or mental improvement in educated clinicians, in another words, the increase of productivity that affects other stakeholders’ economic benefits, and ii) the definition of a starting and an ending point of spread effects. First, we would employ the concept of “compensational demand principle”, in which we think about some compensational exchange situation. For example, if the price of gas goes down, magnitude of monetary effect in salary will be measured as the impact equally on what the individual who buy ten gallons of gas per month. In this case, subjective evaluation for the marginal increase of a monthly salary will be interpreted as the demand price for the technological advantage formed if the price of gas goes down.

Now, turning to the simulation context, we can image an example for the return of resuscitation training on clinicians who have never encountered the simulation. After providing SBME for improving resuscitation skills, all of the clinicians in the community could carry out the treatment in cases of emergencies at any location with no need for delegating the treatment to other clinicians. If such situation arises, local governments may no longer need to hire new specialists for resuscitation. We will be able to estimate the “demand price” for the expected replacement of the improved resuscitation environment if we calculate the lower overall cost of employing unneeded
staff per annum. This is just the calculation of “compensated” clinicians if hired by the local government in lieu of the absence of “educated” clinicians in that community. Then, if we could arrive at the cost of “investing” in resuscitation SBME, the economic outcome of simulation-based resuscitation training would be estimated in the normal CEA procedure.

Table 2 is an example of presenting the function and utilization of BITA according to the SBME context.

Table2. An Example of BITA in SBME Context

<table>
<thead>
<tr>
<th></th>
<th>Hospital with SSC</th>
<th>Management Consultant</th>
<th>Residents in Community</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Investment for SBME</strong></td>
<td>− investment costs</td>
<td>benefit of consultation fee</td>
<td>− additional health costs</td>
<td>Investment -</td>
</tr>
<tr>
<td><strong>Running Costs for Managing SSC</strong></td>
<td>− operation costs</td>
<td>benefit of consultation fee</td>
<td>− additional health costs</td>
<td>running costs -</td>
</tr>
<tr>
<td><strong>Outcome for Reduction in Clinical Time</strong></td>
<td>benefit of time saving</td>
<td>− consultation contract</td>
<td>benefit of time saving</td>
<td>clinical time -</td>
</tr>
<tr>
<td><strong>Outcome for Improving Safety</strong></td>
<td>benefit of additional investment saving</td>
<td>− consultation contract</td>
<td>benefit of law-suit costs saving</td>
<td>safety +</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>investment minus clinical time plus safety +</td>
<td>investment plus clinical time minus safety +</td>
<td>investment minus clinical time plus safety +</td>
<td>investment - clinical time + safety +</td>
</tr>
</tbody>
</table>

4. An Example of ROI in Simulation Education

Here I would like to show a rough and simple example of the estimation of ROI in SBME in accordance with the “compensational demand principle.” To estimate, well identified scenarios, an identified purpose of estimation and mathematical model for the estimation of impact is required. For this I employed a simple simulation method.

**Scenario**

City O, located in western Japan, has one large scale medical university with a highly equipped training hospital. SSC within the university decide to open a program of simulation based emergency resuscitation training for all stakeholders in the city area. And because of this policy, potential trainees in City O must join the program. Because of the training, the total productivity of clinicians in City O would increase, and this in turn may contribute to the optimal treatment of emergency cases, as well as a reduction in emergency transfers by City O’s ambulances.
Purpose of estimation

• To identify the expected end point of diffusion of SBME benefit (meaning the expected outcome of the program in comparison with those of a normal education program.)

• To calculate the reduced costs due to the reduced number of emergency transfers budgeted for ambulance transfer per year.

Simulation Model for Calculation

\[ N(t + \Delta t) - N(t) = \alpha N(t) (N - \overline{N}(t)) \Delta t \]  

Where  
\[ N = \text{the number of educated clinicians} \]
\[ \overline{N} = \text{potential number of targets of education (equal to the total number of clinicians in O minus } N) \]
\[ \Delta t = \text{duration for generating spread effect (in this simulation I set 1 year)} \]
\[ \alpha = \text{a constant number (decided from previous studies : uncertain in here)} \]

The efficiency of ambulance transfers (equal to the increased number of facilities for emergency care)

\[ \Rightarrow \text{in proportion to the number of potential trainees } \left( N - N(t) \right) \Delta t \]
\[ N(t + \Delta t) - N(t) = \alpha N(t) (N - \overline{N}(t)) \Delta t + \beta (N - \overline{N}(t)) \Delta t \]
\[ N(t + \Delta t) = N(t) + \left( \alpha N(t) + \beta \right) (N - \overline{N}(t)) \Delta t \]

Data and Information for Calculation

\[ N = 20,000 \text{ (in City O - 2008)} \]
\[ N = 5,000 \text{ (estimated from several data combinations. See table A)} \]
\[ t = 1 \text{ year} \]

Table A

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trainees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Except</td>
<td>100</td>
<td>150</td>
<td>280</td>
<td>450</td>
<td>770</td>
<td>1350</td>
<td>2800</td>
</tr>
</tbody>
</table>

Calculation procedure

i) \( \alpha \) and \( \beta \) will be calculated from equation (1)(2), and using the average as a constant.

ii) The duration of education for 20,000 clinicians in City O was simulated considering the unobservable technical spread effects on quality improvement.

iii) Using data of actual (observable) transfer costs appearing in Table B.
Table B

<table>
<thead>
<tr>
<th></th>
<th>Total Expense (¥ 1000)</th>
<th>Number of Transfer</th>
<th>Costs Per Transfer (¥ 1000)</th>
<th>Population</th>
<th>Costs Per Population (¥ 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>City O</td>
<td>50200000</td>
<td>205036</td>
<td>244.8</td>
<td>2640000</td>
<td>19.1</td>
</tr>
<tr>
<td>City K</td>
<td>69240000</td>
<td>26464</td>
<td>261.6</td>
<td>670000</td>
<td>10.3</td>
</tr>
<tr>
<td>City ON</td>
<td>2517866</td>
<td>6509</td>
<td>386.8</td>
<td>151189</td>
<td>16.6</td>
</tr>
</tbody>
</table>

Result of Simulation

The results indicate that the number of educated clinicians will increase to include almost all clinicians in City O near 2016. This is about three years before the projected necessary education for the medical students using the regular method (estimated to be near 2019). The economic outcome, ignoring the total amount of investment for the students, would be calculated as

¥150,000 × 20,000 = ¥300 million

*The ratio of transfer reduction was assumed to be 10% while considering unobservable productivity improvement*
5. Conclusion
In this essay I tried to illustrate how to see the genius in the SBME. Many SSC or skills labs, particularly in Japan, are confused as to how best obtain benefits from the program. Although focusing on the improvement of quality and safety in your own facility, as well as of effective education for the students, would be the clearest and the easiest way of identifying simulation benefits, contributing the medical simulation as the quasi-public goods onto the improvement of quality and safety in medical care in society at large is more important for the sustainable health care system. Economic terminology, such as “compensational demand” and “general equilibrium”, as well as “utility maximizing” and “quasi-public”, may sound suspicious to many healthcare professionals because they give the impression of being vague and insufficient. But, from the economic point of view, we sometimes may be inspired by the social viewpoint of health care. Obviously, the ultimate goal of medical treatment and health care must be addressed to ensure a healthy society, for which sophisticated and highly developed techniques, both in medical and surgical care and economics, should be seeking the same goal.

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