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Quantifying complexity in translational research: an integrated approach

David A. Munoz,
Ph.D. candidate in Industrial Engineering and Operations Research, Department of Industrial and Manufacturing Engineering, The Pennsylvania State University, University Park, USA, Telephone: 814-402-0455

Dr Harriet Black Nembhard, and
Professor of Industrial Engineering, Department of Industrial and Manufacturing Engineering, The Pennsylvania State University, University Park, USA, Telephone: 814-865-4210

Dr Jennifer L. Kraschnewski
Assistant Professor of Medicine and Public Health Sciences, College of Medicine, The Pennsylvania State University, Hershey, USA, Telephone: 800-243-1455

Abstract

Purpose—This article quantifies complexity in translational research. The impact of major operational steps and technical requirements (TR) is calculated with respect to their ability to accelerate moving new discoveries into clinical practice.

Design/Methodology/Approach—A three-phase integrated Quality Function Deployment (QFD) and Analytic Hierarchy Process (AHP) method was used to quantify complexity in translational research. A case study in obesity was used to usability.

Findings—Generally, the evidence generated was valuable for understanding various components in translational research. Particularly, we found that collaboration networks, multidisciplinary team capacity and community engagement are crucial for translating new discoveries into practice.

Research limitations/implications—As the method is mainly based on subjective opinion, some argue that the results may be biased. However, a consistency ratio is calculated and used as a guide to subjectivity. Alternatively, a larger sample may be incorporated to reduce bias.

Practical implications—The integrated QFD-AHP framework provides evidence that could be helpful to generate agreement, develop guidelines, allocate resources wisely, identify benchmarks and enhance collaboration among similar projects.

Originality/value—Current conceptual models in translational research provide little or no clue to assess complexity. The proposed method aimed to fill this gap. Additionally, the literature review includes various features that have not been explored in translational research.

Corresponding author: David A. Munoz, dam395@psu.edu.

Keywords

Translational research; Quality Function Deployment; Analytic hierarchy process; Evidence-based; Resource allocation

Introduction

Translational research has appeared in the literature for more than 30 years (Wolf, 1974). However, it was not until early 2000 before it became widely used and studied and translational research publications have been increasing significantly. Additionally, several programs have been initiated to better understand and evaluate translational research and its impact on healthcare outcomes. The National Institute of Health (NIH) managers explicitly made translational research a central priority in their 2003 medical research roadmap (Zerhouni, 2003). As a way to accelerate translational research, NIH staff launched the Clinical and Translational Science Award (CTSA) program in 2006. Currently, there are 62 US academic and medical institutions that receive support from the CTSA. Although there have been over 5,000 publications during 2010 in diverse domains across the translational research spectrum, there is still little agreement on how to measure impact on healthcare outcomes. Poor evaluation and tracking in translational research occurs because it took long to move from basic research to clinical practice; i.e., 17 years for new discoveries to become practiced regularly and just 14% enter day-to-day clinical practice (Westfall *et al*., 2007). Discrepancies in translational research definitions generated various models. Nevertheless, researchers agree that it is important for improving health (Woolf, 2008). The most popular models to understand the translational research continuum are based on T phases or translational blocks. Sung *et al.*, (2003) described the translational process in two phases:

- T1 includes knowledge gained from laboratory testing to developing new diagnosis and treatment tools.
- T2 translates those clinical studies to clinical practice.

Owing to an unclear T2, a three-phase model was proposed by Westfall *et al.*, (2007), Dougherty and Conway (2008). The third translational block (T3), therefore, accounts for the process necessary to implement knowledge. This phase is also known as the practice-based research block. Despite this additional phase, some researchers argued that the model was incomplete and that knowledge implementation was made mostly through physicians' eyes without including other key practitioners when implementing new discoveries (Woolf, 2008). A new phase (T4) was included in the Khoury *et al.*, (2007) model, designed to move from health practice to healthcare outcome. The T4 phase's ultimate success would be to improve public health at lower cost (Kon, 2008).

Currently, most research investments are made in the T1 phase. According to Moses *et al.*, (2005), more than half the NIH budget is spent in basic research. However, evidence demonstrating that this budget allocation results in a maximum impact on people's health is weak. Generating and using evidence to prioritize resource use can accelerate knowledge translation into policy and practice (Glasgow *et al*., 2013). Therefore, evidence is needed to understand how resources are allocated to the different translational research phases to

achieve better healthcare outcomes. To maximize the impact made by T1investment, it is essential to provide an adequate investment in T2 and beyond. Thus, even though some people regard translational research to be strongly associated only with the T1 phase, more effort is needed in the remaining phases to accelerate implementing new discoveries (Woolf, 2008). The publications related to each translational phase also denote the disproportionate attention for the T2 phase and beyond. It is estimated that only 3% of published research is mainly focused on T2, T3, and T4 (Khoury *et al.*, 2007). This imbalance could have negative consequences in health and economics if not properly considered (Woolf, 2007).

To address disagreement in various T models, a general framework based on a process marker model was presented by Trochim *et al.*, (2011), which include process markers or operational steps defined as observable and measurable points specific to the study along the translational research process. The process marker method's main advantage is that it can be used independently or under the T models previously mentioned. Even though the process marker model provides a clear framework to understand translational research and its steps, there is little research determining the process marker's impact on improving and accelerating translation from basic to clinical practice. We present integrated Quality Function Deployment (QFD) and Analytic Hierarchy Process (AHP) to assess and quantify complexity in translational research. The first part extends the marker model since it provides a way to quantify the operational steps' importance for accelerating translational research. Additionally, the framework captures the dynamic drivers along the translation from bench to bedside. Finally, valuable insights are obtained to generate guidelines to better allocate resources and efforts when moving from new discoveries to health outcomes.

Background

Several engineering methods have been successfully applied to address healthcare-related issues (Reid *et al.*, 2005; Kopach-Konrad *et al.*, 2007). However, little attention has been paid to adapting engineering tools to improve and accelerate translational research. Schweikhart and Dembe (2009) apply Lean and Six Sigma to clinical and translational research, arguing that these process-focused strategies can help to accomplish the NIH vision of a more efficient and cost-effective translational science enterprise. In this study, an integrated engineering method using QFD, House of Quality (HOQ) and AHP is proposed to evaluate and quantify complexity in translational research. The QFD component is based on a comprehensive framework to understand customer needs and identify the elements that add value through their eyes. It provides insights to transform customer requirements into product or service characteristics. The HOQ component is used to capture the customer's voice and corresponding technical requirements (TR) that fulfill their needs. Process markers are used as customer's requirements and technical factors are those drivers or elements needed to support those markers. Therefore, the customer could be an individual or institution involved in translating new discoveries into practice. Markers could be: pilot proposal, Internal Review Board (IRB) submission, publishing results, etc. Some TRs could be: administrative support, community engagement, equipment availability, etc. Finally, AHP provides a tool to compare alternatives and/or prioritize various criteria - in our case, markers along the translational research process - to determine their relative importance to achieve a pre-specified goal (i.e., accelerating translational research).

QFD

Quality Function Deployment offers a structured framework to transform customer requirements into product/service features (Akao, 1972). There are several examples that illustrate its applicability and potential benefits in the healthcare. Chang (2006) used QFD to transfer nursing home residents' expectations into improvements. Chaplin and Akao (2003) proposed a comprehensive method for using QFD for the healthcare domain. Their method is based on the customer's voices, organization, process and staff actions. Two Dutch healthcare QFD case studies were presented by Dijkstra and van der Bij (2002); they determined methods for meeting patient requirements in redesign and renewal. In our case, QFD principles are used to understand and identify the key markers and TRs in translational research.

HOQ

House of Quality is a tool used in QFD to capture customer requirements and identify the technical factors that fulfill those requirements. It was proposed by Hauser and Clausing (1988) to improve product quality based on a structured translation of customer needs into measurable TRs. The HOQ can be seen as a conceptual map for quality improvement. Typically, seven elements are needed to build an HOQ framework (Figure 1).

AHP and its healthcare applications

Analytic Hierarchy Process was first proposed by Saaty (1980) to determine the different criteria and compare alternatives based on multiple objectives. This structured technique is a powerful decision making tool that deals with complex, non-linear and multiple-criteria problems. A main advantage is that handles tangible and intangible factors. Additionally, it allows quantifying complex qualitative factors in a structured way. Vaidya and Kumar (2006) present an extensive AHP survey and identify eight main categories in its use: selection, evaluation, benefit-cost analysis, allocations, planning and development, priority and ranking, decision making, forecasting. The AHP application areas are wide and include healthcare. Liberatore and Nydick (2008) reviewed AHP in medical and healthcare decision making. Accordingly, AHP appears to be a promising support tool that can be used in almost every healthcare process/area. Lai (2010) used AHP to evaluate the sustainability of knowledge-based communities in healthcare. Pecchia *et al.*, (2011) used AHP to assess risk factors for preventing falls in elderly population. A novel application of Monte Carlo AHP to rank quality attributes in dental services was proposed by Hsu and Pan (2009). Health technology assessment using AHP by Danner *et al.*, (2011) included patients and healthcare professionals to elicit patient preferences. Although AHP's popularity in the health domains has been growing, few researchers have explicitly investigated its use to help assess and quantify translational research (Cheever *et al.*, 2009).

Integrating QFD and AHP

The literature provides successful accounts that integrate QFD and AHP. Ho (2008) concluded that integrating QFD and AHP is appropriate since they complement each other. Typically, AHP is used to overcome inconsistency in customers' descriptions of relative attribute importance. The AHP weights can be used by QFD tools; e.g., by Chang (2006) to

enhance nursing home service quality. Although QFD-AHP has been helpful in many areas, investigation in its healthcare use is weak, especially in translational research. Our main hypothesis is that using integrated QFD-AHP could help to understand complexity and the factors that accelerate discovery.

Methodology

We propose a three-phase method. In the first phase, the objective is to identify the markers for each phase in translational research and their TRs or drivers. Results are used to present an extended process marker model. The second phase uses the AHP method to determine the markers' absolute and relative importance for each T phase regarding their impact on translational research. Finally, in the third phase, an HOQ model is used to find correlation between TRs and their relative importance for each translational research phase.

Phase I: Markers and technical requirements

The main objective is to identify markers for each phase in the translational research process and the TRs affecting those markers or operational steps. We use the following variables and notation:

$M_{i,j}$: Marker *j* in phase *i*,

$W_{i,j}$: relative weight for marker *j* in phase *i*

R_k: technical requirement *k*

$r_{k,l}$: correlation between technical requirement *k* and technical requirement *l*

$P_{i,k}$: absolute weight of technical requirement *k* in phase *i*

$p_{i,k}$: relative weight of technical requirement *k* in phase *i*

$c_{j,k}$: Impact of technical requirement *k* in marker *j*

where $i = 1$ to I, representing the i-th T phase, $j = 1$ to J, representing the j-th marker, $k = 1$ to K and $l = 1$ to K, representing the k-th and l-th technical requirement respectively.

Brainstorming is used to generate the lists and the recommended brainstorming group size is five to ten participants (Osborne, 1963). Total markers per T phase and TRs should be limited to nine. This number is known as Miller's law, which determines that seven ± two elements is human cognitive capacity's upper limit to process information and make inferences reliably and accurately (Miller, 1956). This number was validated by Saaty and Ozdemir (2003) to reduce judgment inconsistencies. If the markers or TRs exceed nine elements then a Borda count could be used to determine the nine most important elements (Lansdowne and Woodward, 1996).

Phase II. Determining marker weights for each translational research phase

In the second phase, marker weights are determined using AHP. From the marker list (i.e., operational steps in the translational research process) obtained in phase I, the relative importance for each marker is calculated using a pairwise comparison among them. In this phase, consistency is checked to assure valid results. A pairwise comparison matrix is built

to calculate each marker's weight. Each marker pair is compared regarding its importance and contribution to produce an impact on its corresponding translational research phase. The evaluator is asked to determine each marker's importance using a scale from 1 (equally important) to 9 (extremely more important). Saaty (2001) explains why a 1–9 scale is suitable and appropriate for AHP. Table I explains the intensity of importance used for the pairwise comparisons. From the results, a pairwise comparison matrix *A* is constructed:

$$A=\begin{bmatrix} 1 & a_{1,2} & a_{1,3} & \dots & \dots & a_{1,M} \\ a_{2,1} & 1 & a_{2,3} & \dots & \dots & a_{2,M} \\ a_{3,1} & a_{3,2} & 1 & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{M,1} & a_{M,2} & \dots & \dots & \dots & 1 \end{bmatrix}$$

where $a_{1,2}$ represents how much more important is marker 1 with respect to marker 2 regarding their impact on translation. Item $a_{2,1}$ is the reciprocal of $a_{1,2}$. Naturally, the main diagonal is populated by 1s. The pairwise comparison matrix is an $\boldsymbol{M \times M}$ matrix; $\boldsymbol{M(M-1)/2}$ questions are needed to generate the matrix.

After building the pairwise comparison matrix, a normalization procedure is needed to obtain the each marker's relative weight, constructed by dividing each cell value by the sum of its corresponding column represented by *Sj*. Finally, the marker's weight or relative importance is obtained by averaging the cell values across the correspondent row:

$$S_j=1+\sum_{q=1,q\neq 1}^{M} a_{q,j}, j=1,\dots,M$$

$$N=\begin{bmatrix} n_{1,1} & n_{1,2} & n_{1,3} & \dots & \dots & n_{1,M} \\ n_{2,1} & n_{2,2} & a_{2,3} & \dots & \dots & n_{2,M} \\ n_{3,1} & n_{3,2} & n_{3,2} & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ n_{M,1} & n_{M,2} & \dots & \dots & \dots & n_{M,M} \end{bmatrix}$$

$$N=\begin{bmatrix} 1/S_1 & a_{1,2}/S_2 & a_{1,3}/S_3 & \dots & \dots & a_{1,M}/S_M \\ a_{2,1}/S_1 & 1/S_2 & a_{2,3}/S_3 & \dots & \dots & a_{2,M}/S_M \\ a_{3,1}/S_1 & a_{3,2}/S_2 & 1/S_3 & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{M,1}/S_1 & a_{M,2}/S_2 & \dots & \dots & \dots & 1/S_M \end{bmatrix}$$

Thus, the weights for each marker are given by the following column vector *w*:

$$w=\begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ \vdots \\ W_M \end{bmatrix} = \frac{1}{M} \begin{bmatrix} \sum_{j=1}^{M} n_{1,j} \\ \sum_{j=1}^{M} n_{2,j} \\ \vdots \\ \vdots \\ \sum_{j=1}^{M} n_{M,j} \end{bmatrix}$$

Since the values were normalized, the weights will sum to 1. These values are used to present an extended process marker model. Consistency in judgment should be evaluated to minimize errors and make valid inferences at the end of the procedure. To evaluate consistency, an index (CI) and a consistency ratio (CR) must be calculated. To begin, the equation

$$Aw=\lambda_{max}w$$

must be solved for λ_{max}, where λ_{max} *is the average of the maximum eigenvalues*. Then, the consistency index is calculated as:

$$CI=\frac{\lambda_{max}-n}{n-1}.$$

Finally, the consistency ratio can be obtained based on CI and ratio index (RI):

$$CR=\frac{CI}{RI}$$

The values for the *RI* depend on *n* (Table II). Usually, a 0.1 threshold is used to determine if the consistency is acceptable. If a consistency ratio is greater than 0.1 then the evaluator is asked to revise his/her pairwise judgments to reduce inconsistency and be able to make credible inferences (Saaty, 1977).

Phase III. Building HOQ

Building HOQ requires identifying the TRs' impact on markers and calculating TRs' relative importance on each translational research phase. We identified the TRs in Phase 1. Now we quantify the correlation among those TRs. This information is recorded in the HOQ roof. The evaluators decide whether two TRs are strongly positively correlated (9 or ◉), positively correlated (3 or ○), non-correlated (0), negatively correlated (−1 or ×) or strongly negatively correlated (−3 or ※). The procedure should be repeated for each TRs pair; e.g., let's assume that 'Administrative Support' and 'Regulations and Standards' were identified as TRs. If the evaluator believes that those drivers are strongly positively correlated then the correspondent cell should be filled with a '9'.Obtaining the relationship between the TRs and the markers quantifies the driver's impact on the markers. The evaluators respond

whether the relationship between each TR-Marker pair is Strong (9), Medium (3), Weak (1), or No relationship (0). This information is recorded in the relationship matrix, which represents the HOQ body. Calculating the TRs' relative importance for each translational research phase completes the HOQ model's bottom part. After obtaining the absolute weights ($P_{i,k}$) and relative weights ($p_{i,k}$), rankings for each TR can be easily obtained by arranging them in descending order according to their weights. The formulas are:

$$P_{i,k}=\sum_{j=1}^{M} c_{j,k} * W_{i,j} \quad \forall i \quad \forall k$$

$$p_{i,k}=\frac{1}{\sum_{l=1}^{K} P_{i,l}} \sum_{j=1}^{M} c_{j,k} * W_{i,j} \quad \forall i \quad \forall k$$

From this analysis, valuable insights can be obtained about the TRs' relative importance for each translational phase. This can serve as evidence-based guidelines for allocating resources and efforts. In other words, priorities in investments can be determined to achieve a faster impact on health outcomes (Figure 2).

Case study and results

We use a case study to illustrate the proposed QFD-AHP's usability, based on a pilot randomized controlled trial conducted by one author (JK) to evaluate a volunteer peer-led intervention's impact on weight control in primary care. The main research objective is to determine the short-term primary care-based weight control intervention's efficacy in which successful volunteer peers deliver a group-based program. For illustrative purposes, a 3T model was applied by a single evaluator (JK) and the preference results are based on her opinion.

Markers and technical requirements

The markers and TRs identified for the obesity program are shown in Table III and IV respectively. Most markers and TRs could be applied in various initiatives and translational research efforts. We recommend moderation in specifying the markers and TRs. A more general identification allows intervention comparisons across different fields thus more helpful for determining appropriate benchmarks in future studies.

Pairwise comparison matrices, consistency and weights

A pairwise comparison matrix was constructed to compare the markers for each translational research phase. Table V illustrates the pairwise comparison matrix developed for T1.

Table V shows, for instance, that Pilot Proposal ($M_{1,1}$) is moderately more important than Study Proposal ($M_{1,3}$) and that Lab Interventions ($M_{1,5}$) is equally important as Result Analysis ($M_{1,6}$). A similar procedure, to compare one marker's importance, can be made for T2 and T3. From the consistency analysis, all three matrices are consistent. Consistency

ratio values for each matrix are lower than 0.1 and therefore the evaluator's consistency is acceptable (Table VI).

After checking consistency, each marker's weights were calculated (Table VII). According to the weights obtained for T1, for the evaluator, marker $M_{1,1}$ Pilot Proposal is the operational step with the highest relative importance, having a weight of 0.314. For T2, according to the evaluator, the two most important operational steps are $M_{2,1}$ Develop obesity program/Select target and $M_{2,2}$ Submit IRB; each with a weight of 0.223. Finally, $M_{3,1}$ Pressing for public health reform, was the marker with the highest relative importance with a weight of 0.454. From the relative weights, many inferences can be made about which operational steps are critical in this peer-led intervention program. Figure 3 shows an extended process marker model in which the bar height represents the markers' relative importance - graphically valid for markers within a certain translational phase. Therefore, we are not trying to evaluate how important one translational phase is compared to the others but the importance of different operational steps within each translational phase. However, if each phase's relative importance over the others is available (using AHP for example) then the weights should be normalized to graphically reflect their overall importance.

Correlation among TRs and relationship among TR-marker pairs

In Figure 4, correlations between TRs are shown. According to the evaluator, R_1 Collaboration Networks is strongly correlated to R_5 Information Technology. On the other hand, there is no correlation between R_6 Regulations and Standards and R_7 Equipment Availability. The relationship matrix for T1 is shown in Table VIII. The same relationship matrixes were obtained for T2 and T3 (results not shown).

According to the evaluator, the relationship between $M_{1,5}$ Lab intervention and R_7 Equipment availability is strong (9), while the relationship between $M_{1,5}$ Lab intervention and R_2 Administrative Support is weak (1). From the relationship matrix, valuable inferences can be made about the most and least important TRs required dynamically by each marker on each translational phase. This also shows that translational research is dynamic and its needs change over time. The TRs' impact on a marker is not static; it will vary dynamically to fulfill current needs. For example, while R_7 Equipment availability is strongly related to $M_{1,5}$ Lab intervention, it is weakly related with $M_{1,1}$ Pilot Proposal. This information indicates that TRs coordination is necessary to accelerate knowledge translation.

Technical requirements in translational research

With this information, the TRs' importance on each translational research phase can be quantified (Table IX).

As expected, R_3 Funding availability was among the most important TRs for the markers to succeed on each T phase. According to the evaluator, R_1 Collaboration network and R_9 Multidisciplinary team capacity are crucial for T1 and T2. For T3, it is also important to consider R_4 Community Engagement to accelerate translating proven discoveries to practice. The TRs'relative importance or impact on each T phase is shown in Figure 5. From these results, useful guidelines of what and when TRs are critical for each phase can be easily

obtained. Thus, resources can be spent wisely throughout large-scale, complex and dynamic translational research processes (Appendix A).

Discussion

Mapping and evaluating translational research is essential to implement new discoveries. Current translational research models provide few clues on how to evaluate and quantify complex processes - moving from basic science to health outcomes. Trochim *et al.*, (2011) address the discrepancies in translational research by providing a process marker model to map a continuum. Their framework aims to identify clearly definable and measurable steps. One process marker model advantage is that it can be either used independently; i.e., just using operational steps – or under the T phase models used in translational research. Although, their framework helps to identify the different operational steps along the translational research process, there is a need for a robust method to quantify this complexity and evaluate the operational steps' relative importance to accelerate knowledge translation. In the method's first part, a robust framework is presented to map translational research and determine the operational steps' relative importance within the process. Therefore, this approach can be seen as an extended process marker model.

Additionally, the proposed QFD-AHP includes features that have not been previously explored in translational research; e.g., it allows quantifying tangible and intangible elements in a structured way. By understanding each marker and the drivers' importance and impact that make them succeed, resource allocation can be conducted in a smart manner based on evidence. Thus, a more accurate strategic guideline to spend funds, effort, time and resources in different translational research phases can be generated. Consequently, we anticipate that limited resources could be wisely used to support an accelerated, but smoother, journey from basic research to improving public health.

Although the method's main objective is to quantify and evaluate the main operational steps and drivers in translational research, some other useful features are worth mentioning. One is identifying similar projects based on the values obtained for the HOQ model. Usually, similar operational steps and TRs are present in various research and fields. A more advanced analysis could be conducted to identify similar projects based on similarity metrics. This approach could share best practices for similar studies; both between and within fields. Additionally, intra- and cross-disciplinary studies could be promoted based on evidence. Another advantage that can arise from identifying similar projects based on QFD-AHP is generating benchmarks for each operational step. Although we did not provide specific metrics to evaluate markers, similar best practices could be shared and adapted from different projects and compared against the benchmarks. To date, most engineering-based tools, applied successfully to solve healthcare-related problems, have been framed under an operational or tactical vision. Naturally, since translating research from bench to bedside takes time, operational and tactical tools could not be used to understand and cover this scope under a systemic view. The QFD-AHP helps us understand and quantify complexity in the large-scale, dynamic translational research process. Applying the method provides evidence for allocating resources wisely while moving from basic discovery to improved health outcomes.

Conclusions

The proposed QFD-AHP method can effectively quantify the complexity that exists within translational research. This well-structured method is robust and can be generalized to various translational research programs. Moreover, TRs' dynamic impact on the process markers can be identified. Additionally, it provides insights to coordinate those TRs to fulfill the needs at different T phases. The evidence obtained from QFD-AHP can be used to generate guidelines to assure that the proven best-known clinical procedures are transferred into health policy and practice. The proposed method could contribute significantly to translational research by generating agreement on the important markers and TRs necessary when mapping and quantifying complexity, allocating resources wisely, identifying benchmarks within and between disciplines and determining similar research projects to promote collaboration and share best practices. These potential benefits move basic research to day-to-day clinical practice in a more effective and efficient manner.

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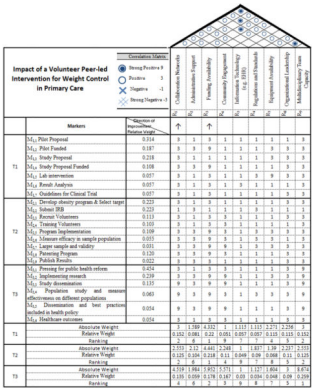
Appendix A: House of Quality



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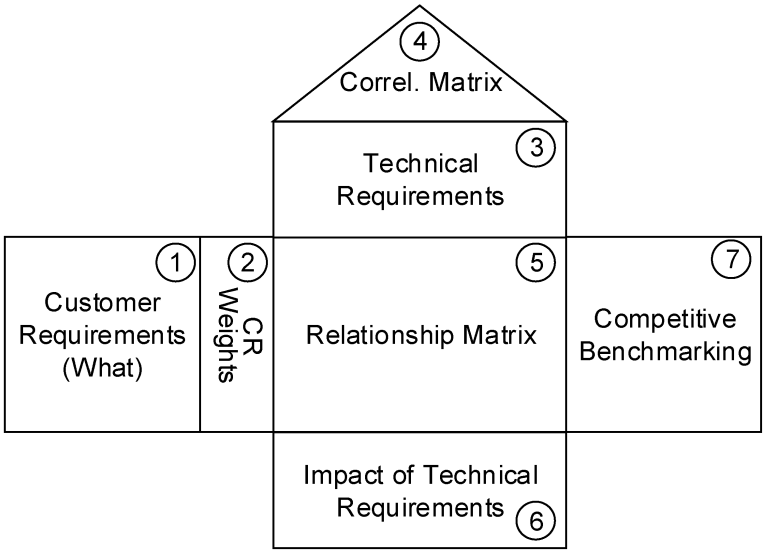

Figure 1.
House of Quality

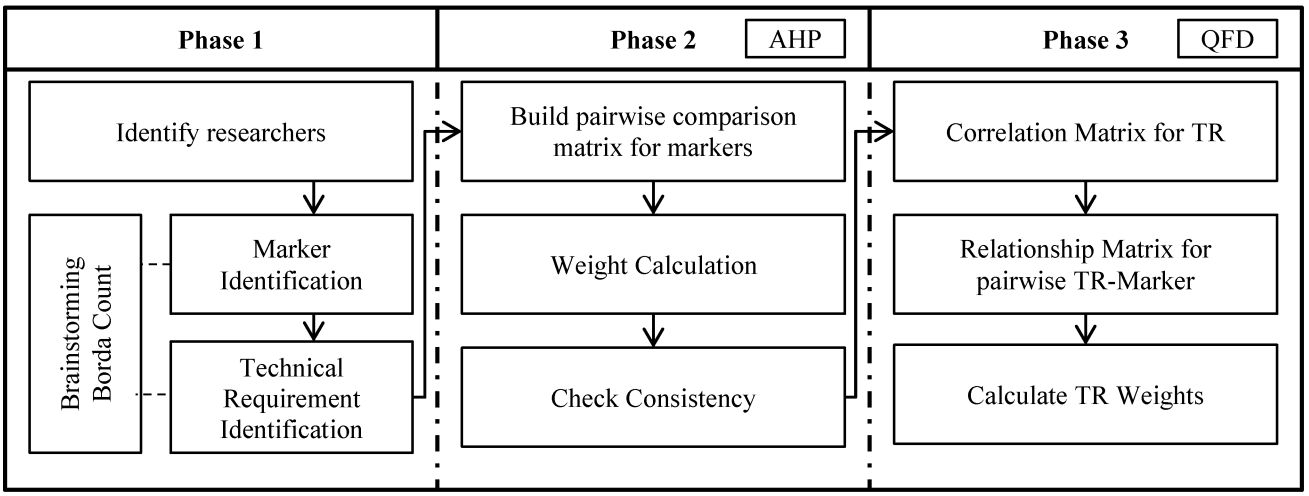

Figure 2.
QFD-AHP Diagram

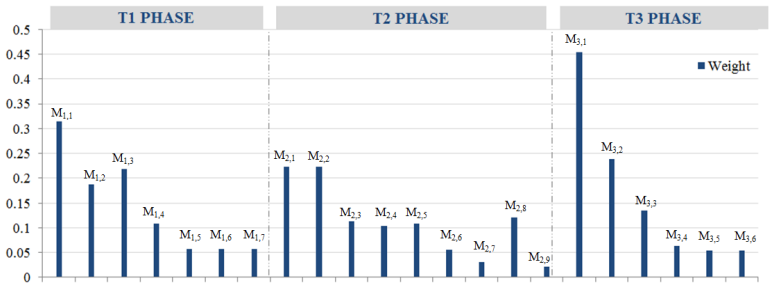

Figure 3.
Extended Process Marker Model

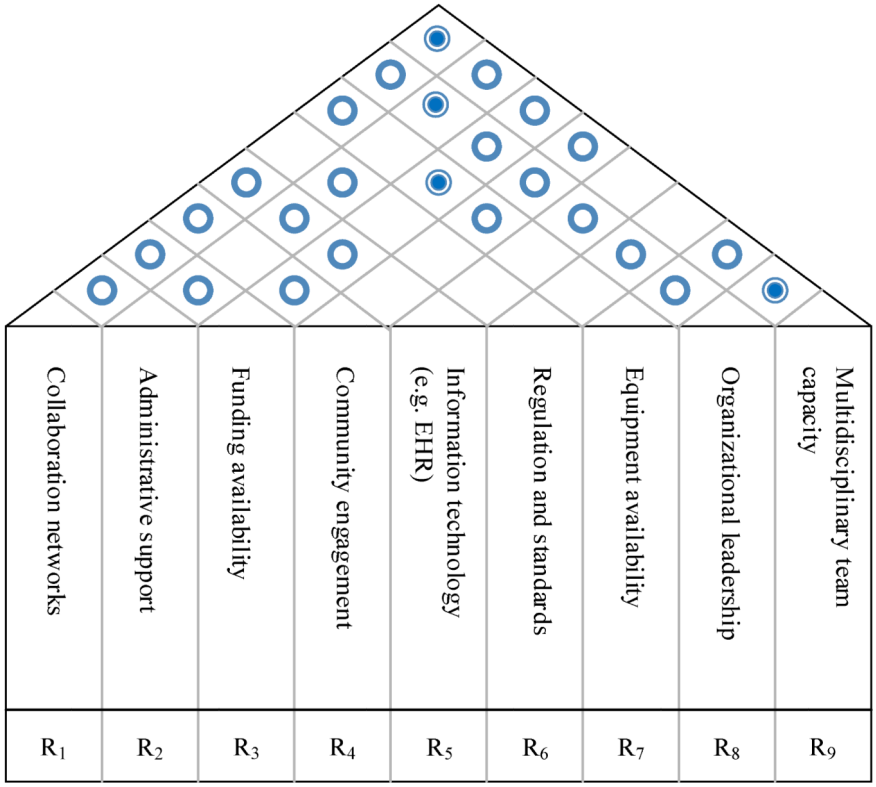

Figure 4.
Technical Requirements - Correlation

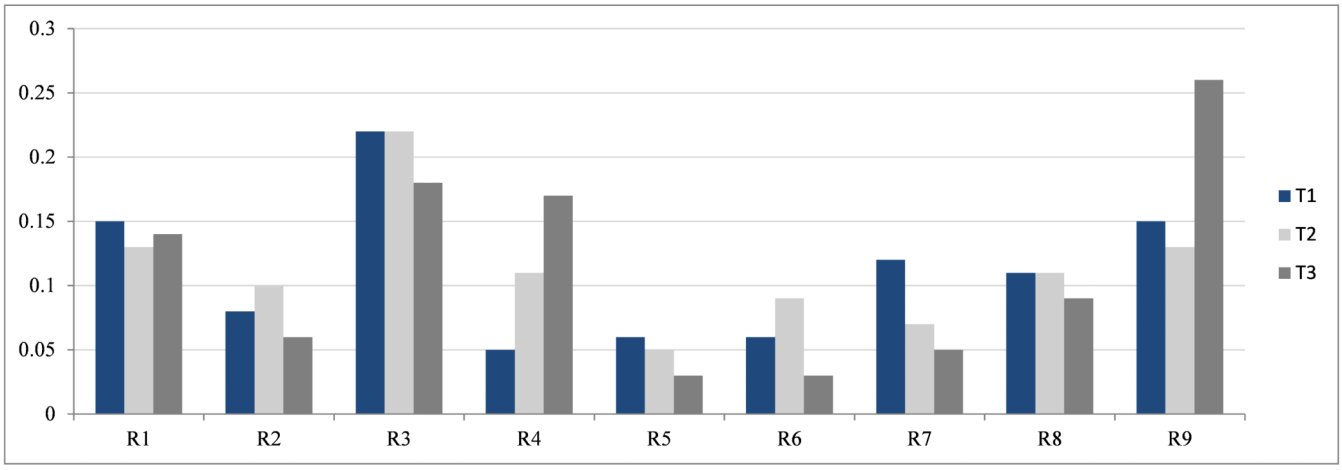

Figure 5.
Relative Importance for technical Requirements on each T Phase

Table I

AHP intensities

Intensity	*Definition*	*Explanation*
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	According to experience an activity is slightly more important than other
5	Strong importance	According to experience an activity is strongly more important than other
7	Very strong or demonstrated importance	According to experience an activity is favored very strongly over the other,
9	Extreme importance	Evidence shows that an activity is absolutely more important than the other
2,4,6,8		Intermediate values

Table II

Random Consistency Index

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Table III

Markers for the obesity peer-led intervention

Phase	*Code*	*Marker Description*
T1	$M_{1,1}$	Pilot Proposal
	$M_{1,2}$	Pilot Funded
	$M_{1,3}$	Study Proposal
	$M_{1,4}$	Study Proposal Funded
	$M_{1,5}$	Lab intervention
	$M_{1,6}$	Result Analysis
	$M_{1,7}$	Guidelines for Clinical Trial
T2	$M_{2,1}$	Develop obesity program & Select target
	$M_{2,2}$	Submit IRB
	$M_{2,3}$	Recruit Volunteers
	$M_{2,4}$	Training Volunteers
	$M_{2,5}$	Program Implementation
	$M_{2,6}$	Measure efficacy in sample population
	$M_{2,7}$	Larger sample and validity
	$M_{2,8}$	Patenting Program
	$M_{2,9}$	Publish Results
T3	$M_{3,1}$	Pressing for public health reform
	$M_{3,2}$	Implementing research
	$M_{3,3}$	Study dissemination
	$M_{3,4}$	Population study and measure effectiveness on different populations
	$M_{3,5}$	Dissemination and best practices included in health policy
	$M_{3,6}$	Healthcare outcomes

Table IV

Obesity peer-led intervention: technical requirements

Code	*Name*
R_1	Collaboration networks
R_2	Administrative support
R_3	Funding availability
R_4	Community engagement
R_5	Information technology (e.g., EHR)
R_6	Regulation and standards
R_7	Equipment availability
R_8	Organizational leadership
R_9	Multidisciplinary team capacity

Table V

T1 – Pairwise comparison matrix

T1	***$M_{1,1}$***	***$M_{1,2}$***	***$M_{1,3}$***	***$M_{1,4}$***	***$M_{1,5}$***	***$M_{1,6}$***	***$M_{1,7}$***
$M_{1,1}$	1	3	3	5	3	3	3
$M_{1,2}$	1/3	1	1	5	3	3	3
$M_{1,3}$	1/3	1	1	3	5	5	5
$M_{1,4}$	1/5	1/5	1/3	1	3	3	3
$M_{1,5}$	1/3	1/3	1/5	1/3	1	1	1
$M_{1,6}$	1/3	1/3	1/5	1/3	1	1	1
$M_{1,7}$	1/3	1/3	1/5	1/3	1	1	1

Table VI

Consistency analysis

Translational Phase	*T1*	*T2*	*T3*
n	7	9	6
CI	0.111	0.139	0.039
RI	1.320	1.450	1.240
CR	0.084	0.096	0.032

Table VII

Marker weights

T1	*Weight*	*T2*	*Weight*	*T3*	*Weight*
$M_{1,1}$	0.314	$M_{2,1}$	0.223	$M_{3,1}$	0.454
$M_{1,2}$	0.187	$M_{2,2}$	0.223	$M_{3,2}$	0.239
$M_{1,3}$	0.218	$M_{2,3}$	0.113	$M_{3,3}$	0.135
$M_{1,4}$	0.108	$M_{2,4}$	0.103	$M_{3,4}$	0.063
$M_{1,5}$	0.057	$M_{2,5}$	0.109	$M_{3,5}$	0.054
$M_{1,6}$	0.057	$M_{2,6}$	0.055	$M_{3,6}$	0.054
$M_{1,7}$	0.057	$M_{2,7}$	0.031		
		$M_{2,8}$	0.120		
		$M_{2,9}$	0.022		

Table VIII

Relationship matrix for T1

Marker	*Weight*	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9
$M_{1,1}$	0.314	3	1	3	1	1	1	1	1	3
$M_{1,2}$	0.187	3	3	9	1	1	1	3	3	3
$M_{1,3}$	0.218	3	1	1	1	1	1	3	3	3
$M_{1,4}$	0.108	3	3	9	1	1	1	1	3	3
$M_{1,5}$	0.057	3	1	3	1	1	3	9	3	3
$M_{1,6}$	0.057	3	1	3	1	3	1	1	1	3
$M_{1,7}$	0.057	3	1	3	1	1	1	1	3	3

Table IX

Technical requirements relative weights

Phase	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9
T1	0.15	0.08	0.22	0.05	0.06	0.06	0.12	0.11	0.15
T2	0.13	0.10	0.22	0.11	0.05	0.09	0.07	0.11	0.13
T3	0.14	0.06	0.18	0.17	0.03	0.03	0.05	0.09	0.26