was to be incorporated. In this case, DEA was studied for its properties to compare the relative efficiency of units according to outputs and inputs.

The steps to recreating this composite index are outlined below. Figure 3.1: index structure demonstrates the partial composition of the hierarchy. Once the hierarchy has been formed, management should outline three random experts from staff that will fill out a single questionnaire together which will determine the relative importance for each composite. This will be the base for the pairwise comparison matrices, which will determine the priority vectors for each composite. The reasoning behind having three random experts from staff undergo a questionnaire together is that one expert alone would provide priorities specific to only one individual, where the chance of skewing the results becomes higher. Whereas, by including two additional experts they bring along a better understanding of the overall business setting. The questionnaire will ask the experts how important a composite relative to another composite at the same level of hierarchy. The rating scale for this importance is demonstrated in Table 3.1: AHP rating scale. The steps taken to develop, and successfully implement, the composite index have been outlined in Table 3.2: steps to creating composite index.

Numerical Rating	**Scale**
1	Equally important
2	Equally to moderately important
3	Moderately important
4	Moderately to strongly important
5	Strongly important
6	Strongly to very strongly important
7	Very strongly important
8	Very to extremely strongly important
9	Extremely important

Table 3.1: AHP rating scale

Once the survey is completed by the experts then the weights are calculated using AHP. The consistency ratio for each composite is determined. If a composite has a consistency ratio above 0.1 then the experts must be asked to determine relative importance for those composites that were inconsistent. Once this process is complete the data is included in the worksheet with the priorities. The data within a composite is added together to get a total amount. This total is multiplied by the weight of each portion of the single composite. This provides the most efficient number for the portion. This "perfect" efficiency number for a portion is divided by the actual number which provides a decimal number. The user must calculate the deviation from 1 to provide a percentage of efficiency for the composite. The deviation from 1 is used because to reach efficiency you want to be as close to `1, or 100%, as possible. But if you are below or above this number you have not reached efficiency. The average percentage of these efficiencies is taken to get an efficiency level for the composite. This is then repeated up to the overall efficiency composite at the highest level of the hierarchy. The final step incorporated DEA to standardize the efficiency across an industry. These steps should be taken to re-create the composite index, either for hospitals themselves, other industries or so that further research can be done into the composite indexes themselves.

4. Hospital Case

The creation, and application, of the composite index required data from a finite number of hospitals. There are six small hospital, three big hospitals, and one educational hospital where the composite index was applied. They were received through the Canadian data conglomerate, Canadian Institute for Health Information, CIHI, which is a non-profit organization that holds essential information on the Canadian healthcare system.

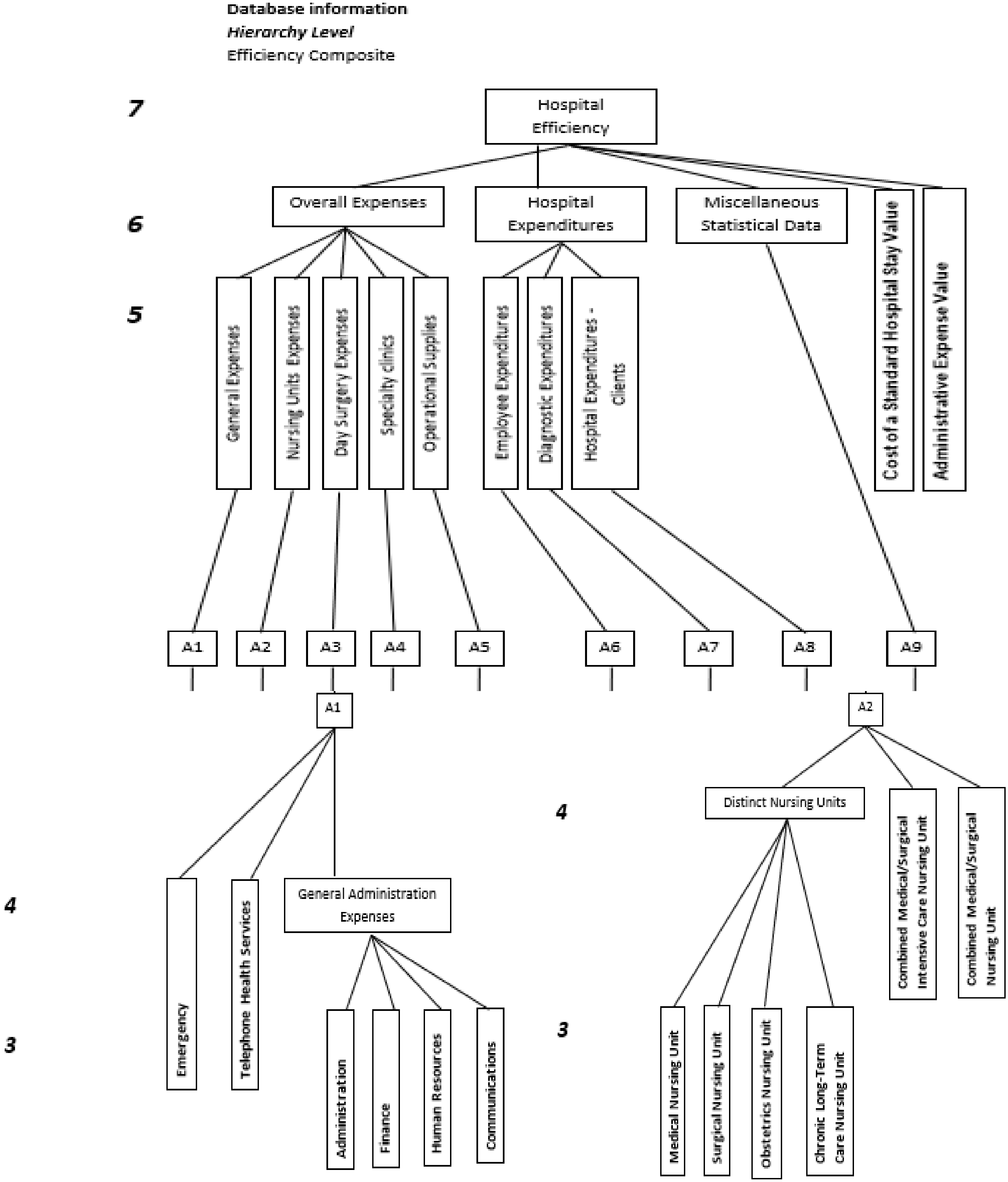

Figure 3.1: index structure

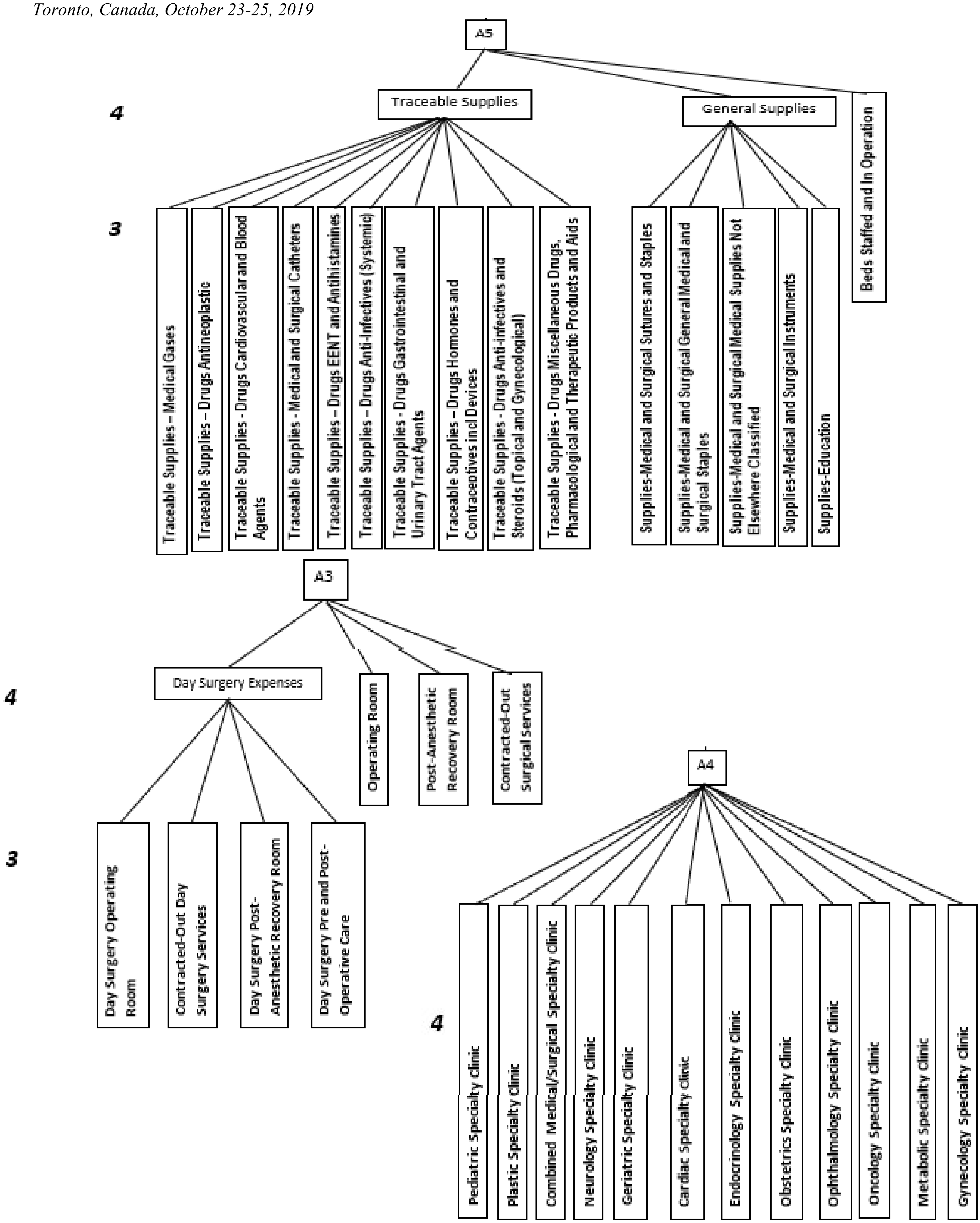

Figure 3.1: index structure

4.1 Data Background

There were one hundred and eleven indicators requested for the purpose of applying this composite index. The indicators were chosen according to the type of data that most hospital classifications would have available, as well as what would be most important to priority setting for a hospital. Under Regulation 964 Public Hospitals Act, these twenty-two different classifications for hospitals in Canada; from Group A to Group V. The classification depends on the number of beds, specific units, and its purpose. This creates a barrier in comparing hospitals as they are not all based on a standardized acute hospital with all the same departments. It is for this reason that this composite index can be incorporated in each type of classification, as portions of the composite index could be removed or added as is needed, while DEA is used to calculate the relative efficiency of the hospitals. From the total number of indicators, forty-one did not have information from any of the ten reporting hospitals. The composite index including these indicators is included in Figure 3.1: index structure.

The composite index is applied to Hospital X, the first preliminary hospital. After all the problems were solved with the original model, nine other hospitals, Hospital A through J had similar composite indexes built and run with their respective data. Hospital X is classified as a small hospital, under CIHI, according to the number of beds. Figure 4.1: level 1 setup for registered nurses shows how the composite is setup for level 1 of the hierarchy, registered nurses. It has the pairwise comparison matrix, priority vector, and consistency ratio. Figure 4.2: registered nurses composite presents the mathematical information computed for the composite.

Table 3.2: steps to creating composite index

Step 1: Review recommended composites that can be included in your composite index.
Step 2: Create hierarchy using the composites and recommended structure for the index.
Step 3: Create surveys with pairwise questions for experts.
Step 4: Survey three experts together for pairwise matrices.
Step 5: Compute the weights using the pairwise matrices, as demonstrated in AHP.
Step 6: Calculate the consistency ratio for each matrix.*
Step 7: Incorporate the data into worksheet for the composite index.
Step 8: Add your alike data for the portions of the composite together to get a total amount.
Step 9: Multiply the weight of each portion of the single composite by the total data provided for that composite to give you a perfect (most efficient) number for each portion.
Step 10: Take the most efficient number for each portion and divide it by the actual to get a decimal.
Step 11: Calculate the deviation from 1 for each portion to get the efficiency of each portion.**
Step 12: Multiply the efficiency of each portion by its respective weight to get the efficiency relative to priority.
Step 13: Sum the efficiencies relative to priority to get the overall efficiency for the composite.
Step 14: Repeat steps 8 through 13 for each composite working upwards towards overall efficiency.
*****Step 15:** Make overall efficiencies of a business in an industry available to conduct DEA so that efficiency levels can be determined relative to other businesses in the same industry.
**If the consistency ratio determines inconsistency in the pairwise matrices, above 0.1, or 10%, then conduct steps 3 through 6 for those specific composites until it is corrected.*
*** The deviation from 1is calculated by taking the first number before the decimal and dividing the decimal number by it.*
****This step can only be applied if additional businesses overall efficiency levels are made available. Either through a database or some kind of program.*

Each component of the index is set-up as demonstrated the first two figures below and calculated in the same manner. Hospital X was determined to be running at 11% efficient with the current priorities. A hospital manager can then look down the levels to see where their largest inefficiencies lie so that they can adjust their strategies to account for operational improvements in those specified areas. Hospital X has an overall efficiency of 11%, however, while this demonstrates its internal level of efficiency, it does not indicate the relative efficiency with other hospitals.

Registered				
	UP Casual	UP Part-Time	UP Full-Time	
UP Casual	1	0.25	0.25	
UP Part-Time	4	1	2	
UP Full-Time	4	0.5	1	
SUM	9	1.75	3.25	
	UP Casual	UP Part-Time	UP Full-Time	Priority
UP Casual	0.111111111	0.142857143	0.076923077	0.11029711
UP Part-Time	0.444444444	0.571428571	0.615384615	0.543752544
UP Full-Time	0.444444444	0.285714286	0.307692308	0.345950346
	UP Casual	UP Part-Time	UP Full-Time	Total
UP Casual	9.066420664	0.459767964	0.722647059	10.24883569
UP Part-Time	36.26568266	1.839071856	5.781176471	43.88593098
UP Full-Time	36.26568266	0.919535928	2.890588235	40.07580682
UP Casual	0.992673993		Lambda	3.068579569
UP Part-Time	0.951566952			
UP Full-Time	1.124338624		CI	0.034289784
			CR	0.059120318

Figure 4.1: level 1 setup for registered nurses

Figure 4.3: scaled efficiencies of Hospitals shows the relative efficiency calculated using DEA, which demonstrates that Hospital X is performing at 53.8% efficiency relative to the other nine hospitals. These internal efficiencies will differ, as they incorporate individualized priorities, and compositions of the index. Nonetheless, both efficiency values provide important information to hospital management.

	Weight	Hours	Perfect Efficiency	Levelled	Deviation	Weighted Efficiency
UP Casual	0.11029711	6013	30166.81115	5.01693184	0.199325012	0.021984973
UP Part-Time	0.543752544	109038	148719.0395	1.363919363	0.733181174	0.398669129
UP Full-Time	0.345950346	158454	94619.14937	0.597139544	0.597139544	0.206580632
	TOTAL	273505			**Efficiency**	63%

Figure 4.2: registered nurses composite

Finally, these ten hospitals had their relative efficiencies determined using DEA. For this study, the outputs indicated were *Administration Expense Value* and *Inpatient Discharges*, while the inputs were *Total Hospital Expenses* and *Total UPP and MOS hours.* These indicators were chosen because the composite index only incorporates statistical and administrative data. Therefore, total expenses and hours were the main inputs of the overall index, whereas for outputs, the administration value and inpatient discharges corresponded appropriately to the inputs. Once DEA is applied, the relative efficiency was calculated by setting the highest efficient hospital to 100% efficiency, and following suit with the other hospitals. In Figure 4.3: scaled efficiencies of hospitals, Hospital D is operating at the highest rate, which DEA determined to be approximately 65%. All efficiencies were then divided by Hospital D's efficiency to determine the relative efficiency once the scale was modified for the highest efficiency to be 100%.

DMU	Efficiency
Hospital X	0.538305158
Hospital A	0.499692873
Hospital B	0.389145559
Hospital C	0.65232731
Hospital D	1
Hospital E	0.365621536
Hospital F	0.542093403
Hospital G	0.754337204
Hospital H	0.72971337
Hospital I	0.184531797

Figure 4.3 scaled efficiencies of hospitals

As the example of Hospital D has shown, the hospital with the highest efficiency relative to the other hospitals becomes the one operating at 100%. The relative efficiency of hospitals is important as it demonstrates how the hospital is performing relative to other hospitals. It provides a manner of comparing the relative efficiency at which hospitals are operating. If all hospitals are operating around the same individualized level of 45% efficient, then relative to one another, it will be close to 100% efficient. But, if a specific hospital is running at 85% efficient and its relative efficiency Is at 60%, it indicates that improvements need to be made to be able to function at a similar level to other hospitals. It is a manner of standardizing the care that is provided by the healthcare industry.

5. Discussion

As a contribution to both the academic community and the workforce, this article provides a detailed guide on how to create an ameliorated method to measure efficiency. It explains the logic behind its development, the steps required to build this form of composite index, as well as a numerical example based in the health care industry. The work done can be applied to other industries and can also be programmed into software to create a program that industry can use as opposed to building themselves. The index demonstrates a manner of using multi-criteria decision-making methodology to determine inefficiencies in a hospital setting. It incorporates an individualized approach at determining priorities as localized staff determine the importance level for comparison matrices. The composite index is adjustable and therefore can be used by all hospitals, no matter the classification. Finally, the relative efficiency calculation allows for all the hospitals to be compared despite their differences in classification. In this manner, management has two important statistics, an internal efficiency level and the external relative efficiency level of the hospital. These statistics can be used to justify strategic planning, operational improvements, budget cuts, etc.

The goal of this work was not only to demonstrate the effectiveness of such a tool to determine individualized inefficiencies, but also to provide additional means for an industry to not only pinpoint their inefficiencies but to standardize them across it. In this way, a business can determine how efficient they are operating according to one another. Nonetheless, this standardization would require that the index be turned into a program that could conduct this external analysis while having the internal aspect remains with the business itself. The steps and example were included in this paper so other industries may incorporate it, as well as for future research in creating a program with the composite index already installed for easier use.

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