2014

Developing a classification for artificial limb services: final report

Robert Gordon
University of Wollongong, robg@uow.edu.au

Michael Navakatikyan
University of Wollongong, mnavakat@uow.edu.au

Janette Green
University of Wollongong, janette@uow.edu.au

Keywords
final, services, limb, artificial, classification, report, developing

Publication Details
R. Gordon, M. Navakatikyan & J. Green, Developing a classification for artificial limb services: final report (Australian Health Services Research Institute, Wollongong, Australia, 2014). http://ahsri.uow.edu.au/chsd/projects/artificiallimbs/index.html

Developing a classification for artificial limb services

Final Report

Updated January 2014

Rob Gordon

Michael Navakatikyan

Janette Green

Table of contents

List of Figures

LIST OF TABLES

1. Introduction

EnableNSW is the government agency responsible for funding the provision of artificial limb services to eligible clients in NSW. Artificial limb services are provided to clients on behalf of EnableNSW by commercial limb manufacturers. EnableNSW is looking to implement a range of policy options, including funding reforms, to improve the effectiveness and efficiency with which artificial limb services are provided. The Centre for Health Service Development (CHSD), University of Wollongong, was commissioned in late 2012 by EnableNSW to undertake a project to contribute to this reform process.

Under the current funding arrangements, manufacturers submit invoices for services provided to EnableNSW clients. Invoices are reviewed and paid provided they comply with EnableNSW funding and policy guidelines. Services provided by manufacturers can be divided into the broad categories of ‘new limbs’ or ‘repairs’. Repairs are classified as minor if the cost is less than \$600, and major if the cost is more than \$600. A client must obtain a prescription for major repairs or new limbs. For some expensive limbs and components, prior approval from EnableNSW is required.

One potential way to improve the efficiency of the current model is to develop a classification system that assigns services into resource homogeneous classes. This offers the potential advantage of streamlining payment arrangements by allowing manufacturers to be paid based on the number of services provided to clients in a particular class rather than being required to invoice for individual services. Under such a scenario, it is important to ensure that the classification system does not have any adverse impacts on either the funder or the provider and equally that the system does not introduce any unintended or perverse incentives.

In this context, the core objectives of the current project were to:

- Undertake a systematic analysis of existing EnableNSW cost and service use data to assess the potential to develop an artificial limb classification system;
- Based on the results of the above analysis, develop a classification system that accurately classifies the range of artificial limb services funded by EnableNSW;
- Test the impact of the classification, using a set of funding rules that could be applied in the payment of artificial limb services.

The project was undertaken in two stages. The first stage involved obtaining data from EnableNSW, developing a study dataset and conducting a range of exploratory analyses. The second stage involved applying recognised classification development principles to produce a recommended classification and an associated set of funding rules.

2. Method Stage 1 - developing a dataset for classification development

The scope and timeframe of this project precluded a prospective data collection being undertaken specifically for the purpose of developing a classification system. As an alternative, retrospective clinical and financial data routinely provided by artificial limb manufacturers to EnableNSW were used as the basis of a series of data analyses during the course of this project.

Not surprisingly, a significant investment of resources was required to consolidate available data into a dataset suitable for classification development purposes. This process was iterative and involved ongoing consultation with EnableNSW as a range of data anomalies and inconsistencies were identified and resolved. When a suitable dataset was compiled, a range of statistical methods were applied to produce a recommended classification system and associated funding model. The impact of applying the classification and funding model on each manufacturer was also assessed.

Data were obtained primarily from EnableNSW financial systems. Manufacturers submit invoices that include details of component and labour costs related to services provided to eligible clients which are entered into a database. Additional information on each client, such as date of birth, weight and activity level is also recorded. For this study, data on 24,742 items from two public and 10 private manufacturers were made available, covering the period January 2010 to October 2012.

The records in the raw data corresponded to the items on the invoices submitted by the manufacturers. A single invoice could have included one or more items. Each invoice related to an “asset” which could be either a repair or a new prosthesis. To create a dataset for analysis, items relating to an asset were combined to a single record as this was to be the unit of counting for class finding.

An initial dataset comprising 6,771 records was constructed in this way. Some items, such as age, weight group and labour hours were derived and also included in the dataset. The 16 variables shown in Table 1 were available for analysis.

Table 1 - Variables available for analysis

#	**Variable**
1	Component cost (total)
2	Labour cost (total)
3	Total number of items invoiced
4	Asset number
5	Asset type (major repair, minor repair, interim, primary, recreational, replacement, secondary)*
6	Equipment/ limb type (of the 45 available alphanumeric codes, only 34 were found in the data)**
7	Equipment/ limb type group (above elbow (AE), below elbow (BE), through elbow (TE), above knee (AK), below knee (BK), through knee (TK), surface work (SW), hip disarticulation (HD))**
8	Number of components
9	Manufacturer
10	Manufacturer group (public, private)
11	Weight
12	Weight group***
13	Age
14	Age group***
15	Gender (male, female)
16	Activity level (K0, K1, K2, K3, K4)

*A small number of other asset types were excluded from the analysis.
** Categories of these variables are provided at Appendix 1.
***These variables have been derived for the purpose of the analysis.

The records in this dataset represent invoices paid by EnableNSW over a period of approximately 2.5 years. Costs from the earlier sub-periods within this period were adjusted for inflation using a statistical adjustment that produced a mean cost for each class. The resulting adjustments were very close to NSW escalation factors for the same time periods.

An exploratory analysis of the 6,771 records was undertaken to assess the impact and coverage of each variable.

3. Results Stage 1 - descriptive analysis

A descriptive analysis of the initial 6,771 records (that is, prior to removal of the public sector records) was undertaken as the next stage of the analysis. The objective was to determine which of the 16 available variables were functioning as cost drivers and therefore warranted inclusion in the classification system.

This analysis indicated that six of the available variables (asset type, limb type, activity level, weight group, age group and the presence of component costs) were functioning as cost drivers. A descriptive summary of these variables is presented in Table 2 to Table 7 below.

In Table 2, it can be seen that more than half the records were classified as minor repairs and almost one quarter classified as replacements. The mean costs of assets in the two repair categories were lower than those in the other categories. The lowest costs were in the minor repair category. There was also considerable variability in the higher cost categories. The most expensive record was a replacement limb which cost $17,472.

Table 2 – Distribution of assets by asset type

	Total invoice cost - all assets				
Group	**n**	**%**	**Mean**	**Standard deviation**	**Max**
Minor repair	3,825	56.5	$233	$213	$3,613
Major repair	663	9.8	$3,061	$1,391	$9,531
Interim	393	5.8	$4,378	$1,689	$11,618
Primary	280	4.1	$4,078	$2,348	$13,969
Replacement	1,526	22.5	$4,607	$2,303	$17,472
Second	41	0.6	$4,486	$1,819	$10,998
Recreational	43	0.6	$3,923	$1,908	$11,412
Total	**6,771**	**100.0**	**$1,945**	**$2,411**	**$17,472**

Table 3 shows the distribution of records by limb type. A large proportion of records related to below knee limbs, which are the most commonly fitted artificial limb. Surface work was, on average, the least expensive, followed by below elbow and below knee limbs. There were records where the cost was more than $17,000 in both the above knee and the above elbow categories. The large proportion of missing records for this variable was not considered to be of concern as all missing records related to minor repairs where this variable was not expected to be a cost driver.

Table 3 - Distribution of records by limb type

	Total invoice cost - all assets				
Group	**n**	**%**	**Mean**	**Standard deviation**	**Max**
Surface work*	193	2.9	$1,687	$663	$3,945
Below elbow	145	2.1	$2,042	$2,073	$12,370
Through elbow	11	0.2	$3,066	$3,007	$7,992
Above elbow	19	0.3	$4,248	$4,053	$17,298
Below knee	2,913	43.0	$2,588	$1,688	$10,814
Through knee	138	2.0	$4,454	$3,652	$11,761
Above knee	760	11.2	$4,827	$3,745	$17,472
Hip	31	0.5	$4,638	$5,107	$13,969

disarticulation					
Missing	2,561	37.8	$182	$83	$1,293
Total	**6,771**	**100.0**	**$1,945**	**$2,411**	**$17,472**

*Surface work includes: 1F - partial hand, 3A - shoulder cap, 4D - toe filler, 4C –partial foot – lynadure (refer Appendix 2 for a list of equipment/limb types)

Table 4 shows the breakdown by activity level for each client based on the 'Amputee K Level Ranking System' (refer Appendix 3). This variable was considered to be an important candidate for inclusion in the classification as it is recognised that the activity level of a client can influence decisions about the type of limb fitted and have an impact on its durability. Again, the large proportion of missing records for this variable was not considered to be of concern as almost all missing records related to minor repairs where this variable was not expected to be a cost driver.

Table 4 - Distribution of records by activity level

	Total invoice cost - all assets				
Group	**n**	**%**	**Mean**	**Standard deviation**	**Max**
K0	270	4.0	$2,222	$2,483	$12,370
K1	243	3.6	$3,269	$2,015	$11,082
K2	1,071	15.8	$3,033	$2,110	$11,839
K3	1,888	27.9	$3,147	$2,687	$17,298
K4	631	9.3	$3,238	$2,668	$17,472
Missing	2,668	39.4	$203	$311	$6,917
Total	**6,771**	**100.0**	**$1,945**	**$2,411**	**$17,472**

The distribution of records by weight group is shown in Table 5. Again, the large proportion of missing records for this variable was not considered to be of concern as almost all of the missing records related to minor repairs where this variable was not expected to be a cost driver. Further, this variable was not subsequently used anywhere in the classification.

Table 5 - Distribution of records by weight group

	Total invoice cost - all assets				
Group	**n**	**%**	**Mean**	**Standard deviation**	**Max**
0 - 40 kg	158	2.3	$3,290	$1,699	$8,564
41 - 99 kg	2,738	40.4	$3,460	$2,467	$17,298
100-124 kg	505	7.5	$3,039	$2,475	$12,468
125+ kg	105	1.6	$3,352	$2,631	$17,472
Missing	3,265	48.2	$394	$992	$12,370
Total	**6,771**	**100.0**	**$1,945**	**$2,411**	**$17,472**

Table 6 shows the distribution of records by age group. The average cost was highest for the 0-16 year age group and decreased with increasing age. However, the differences in cost were not statistically significant as there was a relatively high degree of variability of cost within each age group.

Table 6 - Distribution of records by age group

	Total invoice cost - all assets				
Group	**N**	**%**	**Mean**	**Standard deviation**	**Max**
0-16 years	301	4.4	$2,765	$1,936	$11,185
17-64 years	3,556	52.5	$2,029	$2,603	$17,472
65+ years	2,913	43.0	$1,758	$2,179	$12,265

Missing	1	0.0	$234	-	$234
Total	**6,771**	**100.0**	**$1,945**	**$2,411**	**$17,472**

Finally, Table 7 shows a breakdown of records where labour costs (and no component costs) were reported. Of the 6,771 records, 45% were in this category. As would be expected, the mean cost and the standard deviation of cost were much lower for records which involved labour only when compared to those that also included one or more components.

Table 7 - Distribution of records by presence of component costs

	Total invoice cost - all assets				
Group	**n**	**%**	**Mean**	**Standard deviation**	**Max**
No component costs	3,108	45.9	$249	$362	$4,309
With component costs	3,663	54.1	$3,383	$2,476	$17,472
Total	**6,771**	**100.0**	**$1,945**	**$2,411**	**$17,472**

4. Method Stage 2 - The classification development process

Based on the above analysis, a number of refinements were made to the dataset. Firstly, three of the 10 private sector manufacturers (coded 5, 10 and 13) were excluded from further analysis as each had contributed a very low number of records (from 2 to 9).

Secondly, the cost profile of the public sector and private sector manufacturers was substantially different. It was not possible to determine whether this reflected legitimate differences in cost or simply differences in current funding arrangements or reporting processes. Accordingly, all public sector records (n=769,11.4%) were excluded from the class-finding analysis. These records were, however, subsequently assigned to classes using the resulting classification.

Several other refinements (outlined in Section 4.1) were made to the dataset during the classification development process. Most notably, the initial class-finding analysis was based only on the cost of componentry and did not include labour costs. Following discussions with EnableNSW, it was agreed to expand the original scope of study and include both labour costs and component costs in the classification.

4.1. Overview of the class-finding analysis

The final dataset used in the class finding analysis comprised 6,002 records from seven private sector manufacturers. Regression tree analysis was performed on this dataset to identify potential groups or classes. This approach involves separating records in the data based on a particular variable, known as the dependent variable. Potential classes are generated where records within each class are as similar as possible to each other, and each class is as different as possible from each other class with respect to the dependent variable. ‘Total cost’ was used as the dependent variable for this analysis. Each of the variables described in the previous section was tested to identify which of them resulted in grouping to the set of classes with the best statistical performance.

The results produced from this statistical analysis were compiled and considered by the project team and representatives from EnableNSW. At this point in the process, it was important to assess whether the classes generated through statistical analyses were sensible from a clinical perspective as well as whether the classification would be practical in the funding and policy context in which it would be applied.

Several issues were identified, various models considered and refinements made to reflect the agreed outcomes. The key outcomes of this process are summarised below:

- As noted earlier, the initial class-finding was based on the variable 'component cost' being used as the dependent variable. This was subsequently amended to 'total cost' (which comprises both component and labour costs) to reflect the policy preference of EnableNSW;

- It was agreed that the classes relating to minor repairs would be based on one hour increments of the variable 'labour hours' (which is derived from the variable labour cost). A second model was also developed based on 30 minute increments of this variable. However, this change resulted in inconsistencies in the relative costs between the classes and this second model was therefore rejected;

- It was agreed that there should be an initial split in the classification based on 'new prosthesis' versus 'repairs' to reflect the fundamental difference between these types of service;

- Initially, a model was developed which excluded very high cost records. This approach was in line with the current process where prior approval for such cases is required. After consideration, this model was rejected in preference to a model under which all records can be grouped by the classification. It is noted that policies relating to the payment of high cost cases can still operate in parallel with such a classification.

A technical summary of the statistical analyses undertaken during the project is provided at Appendix 4.

5. The recommended classification system

The proposed classification comprises 19 classes and is based on the following nine variables:

- Prosthesis - repair or new;
- Repair - major or minor (it is recommended that the definition of major and minor continue to be based on whether a prescription was issued for the repair. The threshold for this is currently a cost of $600);
- Component parts – present or not (this applies to the minor repairs classes only);
- Labour hours – number (this applies to the minor repairs classes only);
- Equipment/limb type group (refer Appendix 1 for definitions);
- Complexity – low or high (determined by equipment/limb type group);
- Equipment limb type (refer Appendix 2 for definitions);
- Age;
- Activity level based on the Amputee K-levels ranking system (refer Appendix 3 for definitions).

The classification comprises four main blocks and can be summarised as follows:

All records:

- Records are split initially based on whether they represent ‘repair’ or ‘new prosthesis’;

Repair records:

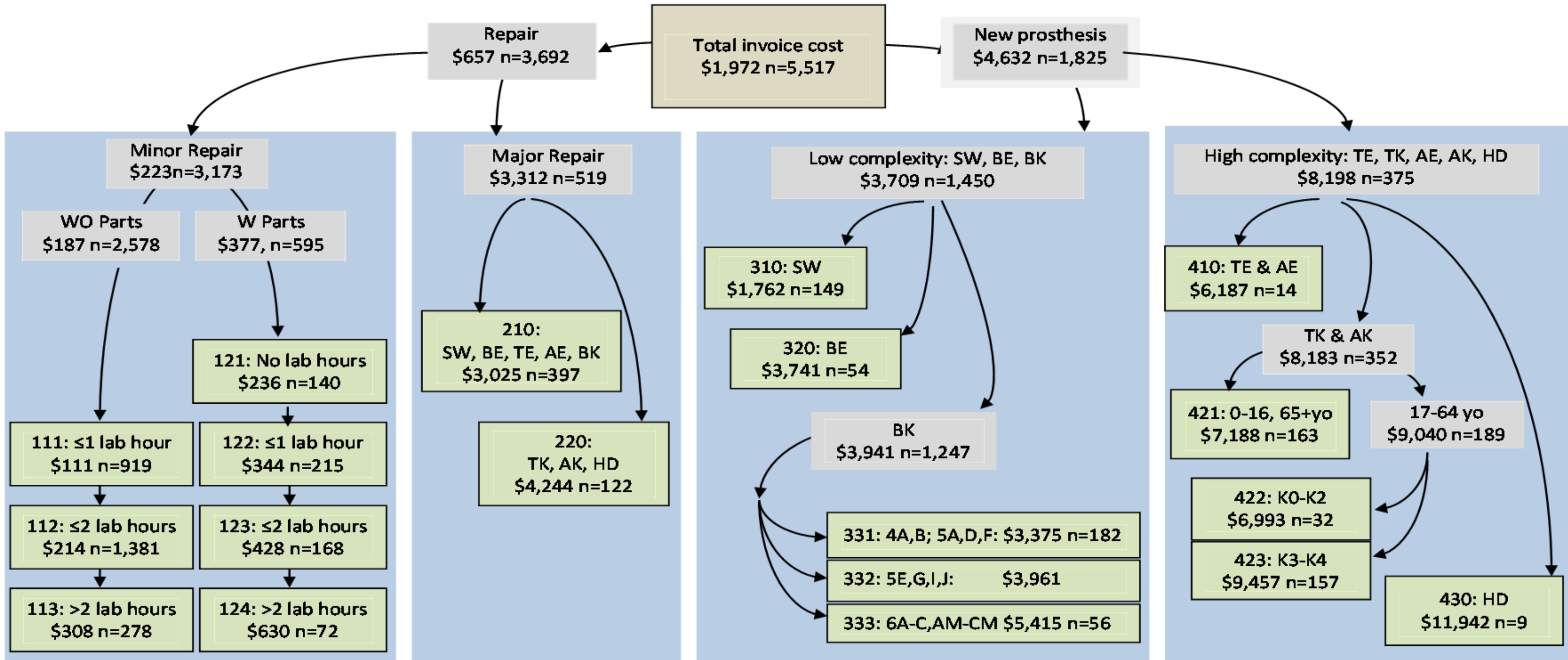
- The repair group is split based on whether the repair was ‘major’ or ‘minor’.
- The minor repair group is further split based on whether or not the repair involved the provision of component parts.
- Within the minor repair group, both the ‘with components’ and ‘without components’ groups are further split based on one hour increments of the variable ‘number of labour hours’;
- The major repair group is further split into two classes based on ‘equipment/limb type group’ (first class: ‘below elbow’, ‘through knee’, ‘above knee’, ‘below knee’ and ‘surface work’; second class: ‘through knee’, ‘above knee’ and ‘hip disarticulation’).

New prosthesis records:

- The new prosthesis group is split initially into ‘low complexity’ and ‘high complexity’ based on ‘equipment/limb type group’ (low complexity = ‘below elbow’, ‘below knee’ and ‘surface work’; high complexity = ‘through elbow’, ‘above elbow’, ‘through knee’, ‘above knee’ and ’hip disarticulation’);
- Low complexity is further split based on equipment/limb type group (three groups: ‘surface work’, ‘below knee’ and ‘below elbow’);
- ‘Below knee’ records within the low complexity group are further split into three classes based on equipment/limb type (first class: 4A, 4B, 5A,5D, 5F; second class: 5E, 5G, 5I, 5J; third class: 6A, 6AM, 6B, 6BM, 6C, 6CM);
- High complexity records are split based on equipment/limb type group (three groups: first group: ‘through elbow and above elbow’; second group: ‘through knee and above knee’; third group: ‘hip disarticulation’).
- The ‘through knee and above knee’ group is further split into two groups based on age (first group: 0-16 and >65: second group: 17-64).
- The 17-64 age group is further split into two classes based on activity level (first class K0-K2; second class K3-K4).

The classification is presented in Figure 1. The overall R-squared statistic of the classification based on the analysis of 6,002 records is 94.7% which represents an excellent statistical performance. It should be noted that the mean costs shown for each class in Figure 1 are based on a trimmed dataset that is described in Section 4.3.1.

Figure 1 The proposed ALS classification



Class number provided as three digit number. Data cover time period from Jan 2010 to Nov 2012. Assets that are not of main seven asset types (‘minor repairs’, ‘major repairs’, ‘replacements’, ‘interim’, ‘primary’, ‘secondary’ and ‘recreational’) or do not belong to equipment/limb type category from 1A to10B (except for minor repairs) belong to Other category and not shown on diagram (n=26).

Abbreviations**: Equipment/Limb Type groups:** BE, TE, AE, BK, TK, AK - below, though, above elbow, and below, though and above knee; HD - hip disarticulation; SW - "surface" work (1F - partial hand, 3A - shoulder cap, 4C – partial foot - lynadure, 4D - toe filler). Refer to Appendix 1 for details of alphanumeric classification of Equipment/Limb types (i.e. from 1A to 11) and Groups. Refer to Appendix 2 for details of The Amputee K-levels ranking system.

The class description, mean cost, minimum cost, maximum cost, CV and class cost relativity or 'weight' are provided in Table 8. The class weights are calculated relative to the overall mean cost of the classification. Again, it should be noted that the values shown for each class are based on a trimmed dataset described in Section 5.1 below.

Table 8 - Class descriptions and costs

Class			Cost details - inliers (private manufacturers)					
Block	**Class**	**Description**	**N**	**Mean**	**Min**	**Max**	**CV %**	**Class weight**
		Total	**5,517**	**$1,972**	**$11**	**$14,729**	**124**	**1.000**
1		Minor repair						
	111	No component cost, >0 and ≤ 1 hour of labour	919	$111	$63	$126	22	0.057
	112	No component cost, >1 and ≤ 2 hours of labour	1,381	$214	$158	$281	16	0.108
	113	No component cost, >2 hours of labour	278	$308	$274	$379	10	0.156
	121	With component cost, no hours of labour	140	$236	$11	$695	83	0.120
	122	With component cost, >0 and ≤ 1 hour of labour	215	$344	$124	$834	52	0.174
	123	With component cost, >1 and ≤ 2 hours of labour	168	$428	$202	$1,069	52	0.217
	124	With component cost, >2 hours of labour	72	$630	$312	$1,209	43	0.319
2		Major repairs						
	210	Upper limb and below-knee prosthesis	397	$3,025	$622	$5,858	31	1.534
	220	Knee disarticulation or more proximal prosthesis	122	$4,244	$700	$5,964	34	2.152
3		New prosthesis – low complexity						
	310	Partial foot or hand, toe filler, shoulder cap	149	$1,762	$495	$2,288	18	0.894
	320	Below elbow (not partial hand)	54	$3,741	$1,895	$5,412	26	1.897
	331	Symes modular/exoskeletal and below-knee exoskeletal design	182	$3,375	$2,653	$4,687	11	1.712
	332	Below-knee, modular and extension design	1,009	$3,961	$3,250	$4,928	10	2.008
	333	Below-knee, thigh-lacer design	56	$5,415	$4,694	$6,378	7	2.746
4		New prosthesis – high complexity						
	410	Elbow disarticulation of more proximal (not shoulder cap)	14	$6,187	$3,906	$8,565	23	3.138
	421	Knee disarticulation and above knee, age 0-16 and 65+ years	163	$7,188	$4,962	$10,656	16	3.645
	422	Knee disarticulation and above knee, age 17-64 years, K0-2	32	$6,993	$5,232	$10,381	19	3.547
	423	Knee disarticulation and above knee, age 17-64 years, K3-4	157	$9,457	$5,114	$13,016	20	4.796
	430	Hip disarticulation	9	$11,942	$10,813	$14,729	13	6.056

5.1. Outlier cases

As noted above, the class finding analysis was based on 6,002 private sector records. As would be expected in a dataset of this size, there was considerable variation in the average cost of individual records within each class. If the classification is to be used to underpin a funding model, it is important that these extreme or 'outlier' cases in each class do not have an unacceptable impact on the mean cost for that class.

It was therefore considered important to identify outliers within each class and produce a mean class value that excluded these records. To identify outlier cases, EnableNSW reviewed the typical clinical profile of cases within each class. Based on this review, the following trimming rules were agreed:

Agreed trimming rules for calculating mean class costs:

- Classes 111 to 112: remove lowest cost 5% of cases;
- Class 113: remove lowest cost 5% and highest cost 10% of cases;
- Classes 121 to 124: remove lowest cost 5% and highest cost 10% of cases;
- Classes 210 and 220: remove cases <$600 and >$6000;
- Class 310: remove lowest cost 5% and highest cost 10% of cases;
- Class 320: remove lowest cost 5% and highest cost 5% of cases;
- Class 331 to 333: remove lowest cost 5% and highest cost 5% of cases;
- Class 410: remove lowest cost 10% and highest cost 10% of cases;
- Class 421: remove lowest cost 10% and highest cost 5% of cases;
- Class 422: remove lowest cost 5% and highest cost 10% of cases;
- Class 423: remove lowest cost 5% and highest cost 5% of cases;
- Class 430: remove cases < $10,000 and >$15,000.

Applying the above trimming rules resulted in excluding 485 private sector records (and 98 public sector records). The remaining 5,517 private sector records were then used to calculate the mean class costs (and other statistics) as shown in Figure 1 and Table 8 above. It should be noted that these records were excluded only for the purposes of calculating mean class costs. The trim points and number of outliers for each class are shown in Table 9.

Table 9 - Trim points and number of outliers by class

Class			**Cut-off, %**		**Cut-off, $**		**Number of outliers**	
Block	**Class**	**Description**	**Low**	**High**	**Low trim point**	**High trim point**	**Low**	**High**
1		Minor repairs						
	111	No component cost, >0 and ≤ 1 hours of labour	5	-	$63	$126	69	0
	112	No component cost, >1 and ≤ 2 hours of labour	5	-	$158	$281	37	0
	113	No component cost, >2 hours of labour	5	10	$274	$379	17	22
	121	With component cost, no hours of labour	5	10	$11	$702	4	28
	122	With component cost, >0 and ≤ 1 hour of labour	5	10	$121	$843	21	26
	123	With component cost, >1 and ≤ 2 hours of labour	5	10	$202	$1,070	10	21
	124	With component cost, >2 hours of labour	5	10	$311	$1,212	4	10

Class			Cut-off, %		Cut-off, $		Number of outliers	
Block	**Class**	**Description**	**Low**	**High**	**Low trim point**	**High trim point**	**Low**	**High**
2		Major repairs						
	210	Upper limb and below-knew prosthesis	-	-	$600	$6,000	34	3
	220	Knee disarticulation or more proximal prosthesis	-	-	$600	$6,000	8	9
3		New prosthesis – low complexity						
	310	Partial foot or hand, toe filler, shoulder cap	5	10	$474	$2,384	8	18
	320	Below elbow (not partial hand)	5	5	$1,205	$5,459	3	4
	331	Symes modular/exoskeletal and below-knee exoskeletal design	5	5	$2,653	$4,700	6	10
	332	Below-knee, modular and extension design	5	5	$3,249	$4,933	86	57
	333	Below-knee, thigh-lacer design	5	5	$4,377	$6,505	4	4
4		New prosthesis – high complexity						
	410	Elbow disarticulation of more proximal (not shoulder cap)	10	10	$3,731	$8,565	1	1
	421	Knee disarticulation and above knee, age 0-16 and 65+ years	10	5	$4,962	$10,666	19	10
	422	Knee disarticulation and above knee, age 17-64 years, K0-2	10	10	$5,227	$10,500	4	5
	423	Knee disarticulation and above knee, age 17-64 years, K0-2	5	5	$5,007	$13,020	8	9
	430	Hip disarticulation	-	-	$10,000	$15,000	3	0
		Total					**346**	**237**

5.2. Applying the classification in a funding context

A core objective of this project was to assess the extent to which the resulting classification was suitable for application in a funding context. To achieve this, each record was allocated or ‘grouped’ to a class in the classification (by definition, each record can be grouped to only one class). The funding for each record was then calculated based on the mean cost for the class together with a set of agreed funding rules.

Both public and private sector records were grouped to allow the financial impact to be assessed at both the manufacturer and sector level. In addition, funding was calculated for all records in the dataset, including those records that were excluded as outliers in the calculation of the class means. This ensured that the full financial impact was measured for each manufacturer.

Finally, prior to calculating the funding level at the record level, it was necessary to agree a set of funding rules. Again, this was undertaken in close consultation with EnableNSW. For records where the cost was within the limits set by the trimming rules for the class, the record was treated as an ‘inlier’ case. For those records where the cost was outside these limits, the record was treated as an ‘outlier’ case.

The following rules were then applied to calculate the funding level for each record:

- For inlier episodes, funding was calculated using the mean cost of inlier cases in the class (as shown in the ‘mean’ column in Table 8). Inliers represented 3,870 cases (92.8%) of the dataset or $6,337,910 (89.9%) of the total funding pool for private manufactures; and 466 cases (88.4%) of the dataset or $649,310 (93.0%) of the total funding pool for public manufacturers.

- For low cost outliers, funding was calculated as the low cut-off value of the respective class (as shown in Table 9). Low cost inliers represented 153 cases (3.7%) of the dataset or $184,039 (2.6%) of the total funding pool for private manufactures; and 52 cases (9.9%) of the dataset or $40,791 (5.8%) of the total funding pool for public manufacturers.

- The funding for high cost outliers was calculated at 100% of the invoice cost. That is, for these records, payment would reflect the actual cost of the service rather than being assigned to the class average. This approach effectively means that funding for high cost cases is determined outside of the classification system because the financial risk for both EnableNSW and the manufacturer would otherwise be too great. Instead, EnableNSW would maintain its policy where the approval of such high cost services occurs on a case by case basis (in the same way that some high cost services are currently treated as discretionary spending). High cost outliers represented 148 (3.5%) of the dataset or $529,385 (7.5%) of the total funding pool for private manufactures; and 9 cases (1.7%) of the dataset or $7,768 (1.1%) of the total funding pool for public manufacturers.

The financial impact was calculated for all manufacturers based on the most recent full year represented in the dataset which was November 2011 to October 2012. The results are shown in Table 10 below. The overall impact across the public and private sectors would be a $23,788 (0.3%) increase in the total funding allocated by EnableNSW.

For the private sector, there would be a very small overall decrease of $8,159 (0.11%) in annual funding across the seven manufacturers. The variation between private sector manufacturers ranges from a decrease of 4.4% to an increase of 6.8%. Although there would be a small net decrease in funding for five of the seven manufacturers, the decrease would be less than 3% for all but one manufacturer.

For the public sector, there would be an overall increase of $31,949 (0.3%) in total annual funding across the two manufacturers. It should be noted, though, that EnableNSW does not expect public sector manufacturers to be funded based on this classification. Their inclusion here is for comparison purposes.

Table 10 - Summary of financial impact: the last year of data (Nov 2011 to Oct 2012)

		Invoice cost		Proposed Classification		Difference	
Manufacturer	**N**	**Total**	**Mean**	**Total**	**Mean**	**Total**	**% Change**
m02	223	$336,251	$1,508	$345,715	$1,550	$9,464	2.81%
m03	304	$374,230	$1,231	$396,715	$1,305	$22,485	6.01%
Total Public	**527**	**$710,481**	**$1,348**	**$742,430**	**$1,409**	**$31,949**	**4.50%**
m01	805	$2,141,265	$2,660	$2,156,114	$2,678	$14,849	0.69%
m06	654	$952,914	$1,457	$936,780	$1,432	-$16,134	-1.69%
m07	614	$981,599	$1,599	$1,048,927	$1,708	$67,328	6.86%
m08	754	$922,376	$1,223	$901,060	$1,195	-$21,316	-2.31%
m11	987	$1,398,372	$1,417	$1,366,303	$1,384	-$32,069	-2.29%
m14	198	$361,214	$1,824	$358,749	$1,812	-$2,465	-0.68%
m15	159	$414,066	$2,604	$395,713	$2,489	-$18,353	-4.43%
Total Private	**4,171**	**$7,171,806**	**$1,719**	**$7,163,647**	**$1,717**	**-$8,159**	**-0.11%**
Grand Total	**4,698**	**$7,882,288**	**$1,678**	**$7,906,076**	**$1,683**	**$23,788**	**0.30%**

6. Conclusion

This project has developed the first version of a classification of artificial limb services. In our view the classification can be used reliably to classify the range of repair and new prosthesis services funded by EnableNSW. The classification comprises 19 classes and demonstrates a very good statistical outcome. The overall R-squared statistic of the classification is 94.7% and the CV for all classes is less than 1.

A core objective of this project was to assess whether the proposed classification is suitable for use in a funding context. Based on our analysis, the classification could reliably be used to underpin a funding model that would equitably share risk between EnableNSW and manufacturers. An analysis of the financial impact of applying the classification to the major private sector manufacturers in NSW suggests that the overall impact would be a very slight decrease in the total level of funding to the sector.

The financial impact analysis presented here is based on current contractual arrangements in place between EnableNSW and private sector manufacturers. A set of cost weights has also been produced which reflects the relative cost difference between classes in the classification. The cost weights range in value from 0.057 from the least expensive minor repair to 6.056 for the most expensive new prosthesis. These cost weights can be used to reflect cost relativities between types of service without limiting the capacity of the market to determine the actual price paid for services.

We would also note that the recommended classification offers important potential benefits from a policy and planning perspective. Casemix classifications are now widely regarded as an important mechanism for counting, characterising and categorising services. Classifying clients into a small number of classes that are similar clinically and that have a similar cost profile can greatly enhance capacity to understand variations in patterns of service delivery and to identify opportunities to improve the effectiveness with which services are delivered.

Appendix 1 - Equipment/Limb type groups

	Limb Group	Abbreviation	Limb Type*	Note
Main	Below Elbow	BE	1A-1E	
	Through Elbow	TE	2D	
	Above Elbow	AE	2A-3C (except 2D & 3A)	
	Below Knee	BK	4A-4B, 5A-5J, 6A-6CM	
	Through Knee	TK	7A-7CM	
	Above Knee	AK	8A-8E, 9A-9B	
Extra	Surface work	SW	1F (partial hand), 3A (shoulder cap), 4D (toe filler) 4C (partial foot - lynadure)	All are low labour cost
	Hip Disarticulation	HD	10A, 10B	High labour cost
Additional	Silesian Belt	SB	11	Separate category, like accessory
	Myoeletric	MY	Myoeletric	Separate category, not limb
	Special	SP	Special	Separate category, unknown
	Not listed	NL	Equip/Limb Type not in the list	Separate category, unknown/error

*Refer Appendix 2 for definitions

Appendix 2 - Equipment/Limb types[1]

No	Note	Description
1A		Below elbow - Work Arm
1B		Below elbow - Dress (S/Suspend)
1C		Below elbow - Dress (Harness)
1D		Below elbow - Work/Dress
1E		Below elbow - Rigid Hinge
1F		Below elbow - Partial Hand
2A		Above elbow - Work
2B		Above elbow - Work/Dress
2C		Above elbow - Modular Dress
2D		Elbow disarticulation
3A		Shoulder cap
3B		Shoulder - Modular Dress
3C	Absent from the data	Shoulder - Standard
4A		Symes
4B		Symes - Compressible
4C		Partial foot - Lynadure
4D	Absent from the data	Toe filler
5A		Below knee - PTB Exoskeletal
5D		Below knee - PTS Exoskeletal
5E		Below knee - Modular PTB
5F		Below knee - PTK Exoskeletal
5G		Below knee - Modular PTK
5I		Below knee - EXTENSION
5J	Absent from the data	Below knee - EXT MODULAR
6A		Below knee - Thigh Lacer S/S
6AM		B/K T/L S/S - Modular
6B	Absent from the data	Below knee - Hard Socket
6BM	Absent from the data	Below knee - Modular Hard Socket
6C	Absent from the data	Below knee - Ischial Bearing
6CM	Absent from the data	Below knee - Mod Ischial Bearing
7A		Through knee
7B		Through knee O/S irons leather T/L
7BM	Absent from the data	Through knee O/S irons leather T/L modular
7C	Absent from the data	Through knee O/S irons plastic T/L
7CM	Absent from the data	Through knee O/S irons plastic T/L modular
8A		Above knee - Total contact exoskeletal
8B		Above knee - T/contact modular
8C		Above knee - Standard stubby
8CM		Above knee - Modular stubby
8D		Above knee - Extension
8E		Above knee - Ext modular
9A		Above knee - Pelvic band
9B		Above knee - P/B modular
10A	Absent from the data	Hip disarticulation
10B		Hip disarticulation - Modular
11	Absent from the data	Silesian Belt

[1] Classification of equipment/ limb types based on data provided by EnableNSW.

Appendix 3 - The amputee K-levels ranking system[2]

- **K0** – No Mobility. This base level is assigned to amputees who do not have the ability or potential to ambulate or transfer safely with or without assistance. A prosthesis does not enhance the quality of life or mobility of the amputee.

- **K1** – Very Limited Mobility. The amputee has the ability or potential to use a prosthesis for transfers or ambulation on level surfaces at a fixed walking pace. Walking at various speeds, bypassing obstacles of any kind are out of the K1 class.

- **K2** – Limited Mobility – The amputee has the ability or potential to use a prosthesis for ambulation and the ability to adjust for low-level environmental barriers such as curbs, stairs, or uneven surfaces. K2 level amputees may walk for limited periods of time however, without significantly varying their speed.

- **K3** - Basic to Normal Mobility. The amputee has the ability or potential to use a prosthesis for basic ambulation and the ability to adjust for most environmental barriers. The amputee has the ability to walk at varying speeds.

- **K4** – High Activity. The amputee exceeds basic mobility and applies high impact and stress to the prosthetic leg. Typical of the prosthetic demands of the child, active adult, or athlete.

[2] Website accessed 27 September 2013 http://www.amputee-life.org/2012/10/28/amputee-k-levels/

Appendix 4 - Technical description of statistical analyses

Classification building

Statistical analysis was done using the R programming language. The regression tree splits were found using recursive partitioning algorithm implemented in the *rpart* package of R. Decisions to adopt a split were based on cross-validation R-square value (cross validation error) in conjunction with a conservative 1 standard error (1SE) rule.

In undertaking the statistical modelling, the following casemix principles were applied:

(a) priority was given to using higher-level grouping variables first rather than nested lower-level variables (i.e. to use equipment/limb types groups with 8 categories before equipment limb types with 45 categories);

(b) effort was placed on creating classes with sufficient volume;

(c) statistical solutions were verified by expert assessment. Thus, the resulting classification is a model built using mixture of statistical assessment and expert advice. The levels of the splitting variables which were not represented in the data, were also allocated into classes after discussion with experts.

Major classification blocks

Statistically, minor repair is a very distinct group, and naturally splits from other records. That is not the case with the major repairs, which is closer in cost new prosthesis records. However, it was considered clinically sensible to distinguish all repairs from all new limbs, despite little gain in predictive power. On this basis, the four major blocks of the classification were agreed. Table 11shows the comparative statistical performance of the models with all four major blocks and with major repair and low complexity new prosthesis together.

Table 11 - Comparative performance of models for major classification blocks

Regression tree models	Number of classes	R-square, %	
		Ordinary	Cross-validation*
Major four blocks model built (selected)	4	84.5	84.4
Three blocks model with joint major repairs- low complexity new prosthesis class	3	84.2	84.2

* Cross-validation R-square is considered more reliable than ordinary

Minor repairs

There were only two splitting variables that were driving the cost of minor repairs: ‘number of labour hours’ and ‘presence of component parts’. Labour hours are calculated as labour cost divided by $126.2, the highest hourly rate for the time of the analysis. Using the highest value of labour rate is important for separation of the cases "leaking" to the higher class. For example, if the actual rate was $126.10, and we divided labour cost for one hour by rate $123.10, the resulting hours of 1.02 will be mistakenly classified as between 1 and 2 hours category.

The analysis returned two competing models: with 7 classes (which was finally adopted) and with 4 classes (with and without component parts, with < 1 and ≥ 1 labour hour). The simpler model is suggested but 1SE rule, while the more complicated model gives the best cross-validation performance and was approved after discussion (see table below).

Table 12 - Comparative performance of models for minor repairs

Regression tree models	Number of classes	R-square, %	
		Ordinary	Cross-validation
Model with 7 classes (selected)	7	40.6	39.9
Model with 4 classes	4	36.0	34.2

Major repairs

Statistically the best model comprised 3 classes. First split suggested by the algorithm was by ≤2 versus > 2 labour hours with mean class value $647; the second split was given as in the accepted classification. However, the first split was deemed to have no clinical sense, because cost < $600 is not major repair by definition, and these assets are outliers. Thus, the number of labour hours variable was removed from the model. The final two class model is recommended by 1SE rule. It can be split further gaining 2.3% of extra reduction in variance. However, one of the resulting classes would be too small (n=23, Mean = $1,563), and the split was disregarded.

New limb: low complexity assets

Splitting low complexity asset required the priority to be given to higher-level variable, i.e. to equipment/limb type groups, rather than to equipment/limb types. Under this condition the first split recommended by 1SE rule was for surface work versus others. After a discussion an additional split into below elbow versus below knee class was introduced. The below knee class was further split into three using 1SE rule. Thus, the final structure with five classes was accepted. The equipment/limb type categories 4D, 1E, 5J, 6B, 6BM, 6C, and 6CM were not represented in the data and were allocated to their classes after discussion.

New limb: high complexity assets

The following variables were not used for the analysis as being introduced to describe the minor repair class: Labour hours and Presence of component cost flag. Equipment limb type group was used in preference to Equipment/limb type, being a higher level variable. The best statistical model following 1SE rule was three-class model with two splitting variables: age and activity level. This was not considered to be clinically sensible primarily because activity level does not apply to upper limbs and because hip disarticulation forms a distinct group. This option was therefore rejected. The following two additional classes were created and forced into the model: (a) through/above elbow equipment/limb type group and (b) hip disarticulation. The remaining through/above knee equipment/limb type group then naturally split by 1SE rule by age and level of activity.

Method for escalating costs over multiple years

The following model that predicts invoice cost and includes the escalation factors as independent variables was optimised using the *optim* function of the R base package. The factors were found by adjusting for derived artificial limb classification classes as confounding variables. Calculations were performed on subset of data from private manufacturers. Prior to modelling, each invoice cost was grouped into one of 19 classes of the classification.

At the first stage all invoice costs were multiplied by financial-year specific escalation factors (three factors for 2009/10, 2010/11 and 2011/12). Then, the mean costs for each of 19-classes were found by fitting a linear regression model without intercept. Then the means were divided by year specific escalation to predict the invoice cost. The sum of squares of the differences between predicted and data cost was minimised. The resulting factors are shown in the following table with the general escalation factors used in NSW.

Table 13 - Escalation factors used for modelling

Escaltion factor toward 2012/13 financial year	Used for modelling	NSW
From 2009/2010 to 2012/13*	1.2278216	1.086371
From 2010/2011 to 2012/13	1.071692	1.055754
From 2011/2012 to 2012/13	1.026382	1.026

*This escalation factor is derived on 9 data points only, and is of no real influence