AUT ENTERPRISES LIMITED

Response to County of Allegheny Request for Proposal to Design and Implement Decision Support Tools and Predictive Analytics in Human Services

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Executive Summary

This RFP is of national and international significance. It provides the opportunity for Allegheny County to be at the forefront of research and practice, and showcases how big data could be deployed for better outcomes for children in welfare.

The main focus of this proposal is the automated identification of children (via predictive risk modelling) as they move through child welfare. Predictive risk models (PRMs) are algorithms which automatically generate a risk score (1 to 100) indicating the probability that a child in contact with services will have a future adverse event. These adverse events could include substantiated maltreatment, placement in foster-care or even rare events such as death. The algorithm could be run at a variety of points such as at first agency contact, first home visist or at placement. These risk-scores could be interrogated by appropriately credentialed front-line staff. Children with elevated risk could be automatically referred to appropriate support agencies or specially trained social-workers. The risk score information could be aggregated up to agency, service or sub-population levels, and outcomes tracked for high-risk groups, enabling the DHS to undertake the live monitoring of risks and outcomes in sub-population. Risk scores could be used for performance based contracting with providers, with risk-scores providing a way of standardising case-loads.

We have formed a multi-disciplinary, international collaboration lead by Professor Rhema Vaithianathan, a health economist. The team includes economists Professor Tim Maloney (AUT) and Dr Nan Jiang (AUT), and social work Assistant Professors Dr Irene De Haan (University of Auckland) and Emily Putnam-Hornstein (University of Southern California). This team developed one of the first automated models to identify (from birth to two years of age) children in contact with the public welfare system who will become victims of maltreatment (see Vaithianathan *et al 2013*). They have shown that high risk children could be identified more than 2 years before the maltreatment occurred – thus providing sufficient lead-time in which intervention is possible. Professor Vaithianathan has experience in implementing predictive risk models in complex multi-agency settings. The team will contract with a Pittsburgh-based researcher with a social-work policy background to provide on-the-ground and day-to-day liaison. A disparities researcher will also be contracted to evaluate the impact of this project on outcomes for African Americans and children of color. These individuals will be chosen in consultation with the DHS. We also include the option of implementing the predictive risk model(s) in collaboration with Erudite Software, a boutique health software consultancy.

A major emphasis of the proposal is to build a collaborative approach to the project, involving partnerships with frontline staff and agencies. Developing highly predictive algorithms is easy, changing the practice and management of children is difficult and requires collaboration with end-users. We believe our project has an excellent potential to be a game-changer for the use of data in improving outcomes for vulnerable children and their families. This funding request is in the range of $279,374 to $576,024 depending on functionality.

Organization description

Research Team's Experience and Expertise

Researchers for this project are based at The University of Auckland, AUT and The University of Southern California. The contract will be managed by AUT Enterprise Limited (AUTel) which is a wholly owned subsidiary of AUT University, and was established as the commercialisation arm of the University. AUTel is a member of UCONZ, the University Commercialisation Offices of New Zealand, AUTM, the international Association of University Technology Managers, and Unicom Consortium –a Pre-Seed Accelerator Fund Investment Group. AUTel engages with industry, investment and commercial networks to bring new technologies to the market.

If we win the contract, AUTEL's intention is to explore registering a business in Allegheny County as a wholly owned subsidiary of AUTEL prior to the commencement of the project. This would be a foreign owned LLC and would be subject to state and federal corporate taxes.

The multi-disciplinary, international team is comprised of researchers who have all had extensive experience working in *inter alia* frontline social work organisations, policy agencies and NGOs. The team have worked together for a number of years in implementing predictive risk models for health and human services. All members of the team are committed to having a long term impact on improving outcomes for children and reducing disparities in outcomes. Their translational research program is directed toward this end goal.

The team is lead by Professor Rhema Vaithianathan, a health economist and an international expert on the application of predictive risk modelling in health and human services. She has undertaken research on predictive risk modelling in New Zealand, the UK, Singapore and the US. She has a PhD from the University of Auckland and was previously a Harkness Fellow at Harvard Medical School. She has also led teams which have successfully implemented predictive risk models in complex health and human service settings.

Predictive risk models (PRMs) are automated algorithms which generate a "risk score" when an individual comes into contact with an administrative database. The risk score indicates the probability that the person will experience an adverse event in the future. For example, all children who register on a public benefit system could be risk scored for their likelihood of being a victim of a substantiated maltreatment finding by age five (Vaithianathan *et al (2013)*). The risk score is generated using data about the individual that is routinely captured and stored in administrative databases and requires no human input. PRM allows large populations to be easily and cost effectively screened. The idea is that the score can then be communicated to agencies and professionals who are able to priorities high risk individuals and families for services which are designed to prevent the adverse outcomes.

Erudite Software

Erudite Software is a boutique health software design firm specialising in customised software solutions and analytics for the health and human services sector. They are based in Auckland but have undertaken a range of international projects. They have developed a number of decision tools for clinical and professional use in the field. They are able to work closely with the research team.

Erudite have undertaken a range of customised solutions that include

- software running across multiple time zones and multiple languages,
- software running for large corporate and public sector companies,
- health data analytics for government agencies, international insurers, district health boards and corporate health funders

Erudite has collaborated with research teams from both AUT and The University of Auckland. Their experience and expertise in working with large sets of sensitive data attests to their deep familiarity with data interface design and methods, at both collection and delivery methods, at both collection and delivery.

Note that the software sub-contract with Erudite is optional. We are happy to work with in-house IT expertise – or an alternative vendor – to implement the PRM.

In this section, we will describe in detail two projects that members of the team have undertaken. The first is implementing a PRM which automatically scores patients leaving hospital as to their risk of an unplanned admission. The second is a project developed for the New Zealand Government which automatically identifies children who are most at risk of having a substantiated maltreatment finding by age five.

The Auckland Predictive Risk Model for Identifying Patients at Risk of Emergency Readmission

Vaithianathan and Jiang have been working with hospitals in New Zealand for the last five years implementing PRM ((Jiang and Vaithianathan, 2012). In this project, patients who are discharged from the Auckland public hospital system (comprising three hospitals which serve a population of 1.4 million) are automatically assigned a risk score. This score (from 1 to 100) indicates the likelihood that the patient will be readmitted to hospital for an unplanned emergency in the following 365 days. The patient's name is automatically matched to the enrolment data from physician groups in the region. Family physicians are emailed the names of their patients who have been discharged within the previous week, whose risks scores have exceeded the cut-off threshold. Physician groups then proactively follow up with these patients to try and reduce their readmissions. We are currently evaluating this tool.

All stages are automated and information is "pushed" on to the relevant decision-maker. Of course the family physician can decide to ignore the risk score if they choose. The reason for

this low-key approach is that we believe that highly prescriptive approaches to changing professional practice is not sustainable.

The PRM tool for hospital emergency admission was developed using (anonymised) hospital admission data that was provided to the researchers from each of the hospital's central data warehouses. Logistic regression methods were used to develop a variety of algorithms. We worked closely with the IT departments in each hospital in order to understand their individual coding practices. This experience suggested that early engagement with the in-house IT and data warehouse teams are key to smooth implementation. For example, we discovered a number of anomalies in the timing and coding practices at each site, and as a result we had to develop variants on a base model which could be implemented at different points in the data feed. One algorithm was implemented at the point of admission and was used by the hospital to identify patients who could benefit from in-hospital programs designed to reduce the chances of readmission, such as better discharge planning. The other produced a risk score at the end of the hospital stay, and alert the family physician about the discharge of a high risk patient. These algorithms are currently being used in the field.

The project was overseen by a group of end-users (family physicians, practice managers, nurse practioners and emergency room physicians), and chaired by an extremely committed family physician who served in one of the most deprived areas in Auckland. Other members of the team were hospital specialists, community based nurses and health care managers. The project also had Ministerial (Federal) support as it was part of a national strategy to improve the integration of health services.

Prior to disseminating the risk scores to the end-users we subjected our methods to rigorous quality assurance. We asked each hospital run the algorithm for three months of live feed data but not to disseminate it to end-users. We checked the prognostics of the fielded tool against the development tool and determined that its predictive power in the field was equally strong. After confirming the prognostic strength of our procedure, the risk score was next disseminated on a monthly basis to a few family physicians at trial sites. Practice nurses from these trial sites were brought together for a half day workshop with Professor Vaithianathan and the implementation team to learn how the algorithm worked. They acted as the liaison with the family physicians and "presented" the risk scores to the physicians in their own clinics. They were all supplied with Vaithianathan's cell phone number and were encouraged to call her if they had technical questions or if the family physician sought further clarification. As a result, we received a few calls. Some of these were from physicians seeking better understanding of the science, others alerted us to bugs that arose in the tool's deployment. Thus were able to address misunderstandings and eradicate bugs before the tool went out to all sites.

The hospital risk scoring system is now fully implemented across all sites in the greater Auckland region. At this stage of the project it is left up to the professionals to decide what they will do with the lists of high risk patients that are emailed to them on a regular basis.
We find that some of the physicians are actively using the "risk lists" in working with their high-risk patients so as to manage them better in the community. Moreover, we have found that while physicians were initially sceptical of the validity of the risk-score, as they

have tracked high risk patients over time, they have discovered that their own professional intuition as to who is most at risk has not been as predictively reliable as they may have initially believed.

Following the implementation of the tool, Rhema Vaithianathan was asked to evaluate the impact of the project. However, we believe that it is not good practice to evaluate one's own programs and we have arranged for a group of researchers who were not involved in the project to evaluate its impact on re-hospitalization rates. This evaluation work is currently being undertaken.

Predicting Children at Risk of Maltreatment

A second project that the research team has worked on (which is much closer to the project we propose to undertake with Allegheny County) is the development of a PRM that can help identify and prioritize the needs of children who come into contact with welfare agencies. This project involves using integrated CPS and public benefit data to develop a predictive risk model which would generate a score for children prior to age 2, as to their risk of being a victim of substantiated maltreatment by age 5. The research is reported in the *American Journal of Preventative Medicine*, (Vaithianathan *et al* 2013). We are currently awaiting approval from Government before implementing this research in a trial format within the field.

This project has involved very close collaboration with the Ministry of Social Development (the Federal Agency responsible for CPS). Vaithianathan was the PI on the project. At the commencement of the project, she met with the Federal legislator in charge of CPS (Minister of Social Development) to ensure that the legislators knew the team. She also ensured that ethical and disparities investigations was a strong of the project as was an analysis from the indigenous community, co-opting members on to the team as required. Vaithianathan as PI was responsible for selecting the team members and overseeing the research program. The prototype risk model was developed by the research team using anonymised data that was supplied by the Government Department. The methods employed and the prognostic strength were high.

Ethical analysis of the policy involved two major areas: its broad legitimacy as public policy, and its legitimacy from the indigenous people's point of view. To address the former concern, we had the project independently evaluated by Associate Professor Tim Dare, a philosopher specialising in Public Policy Ethics. To address the latter, we brought together a group of indigenous researchers and practitioners in a series of workshops, the results of which were drafted into a document. Our research findings ultimately formed the basis for an initial government policy paper (a white paper) on vulnerable children.

Subsequent work done in-house by the Ministry has shown that better prognostic strength can be achieved with additional data from health and birth records – these results are as yet

unpublished – but illustrate that an integrated data set such as that available to Allegheny County can produce highly accurate risk scores.

As part of her role on the project, Professor Vaithianathan had to make presentations to Parliamentary Select Committees, senior administrator and opposition politicians. She has also had to undertake national media interviews and presented the research at conferences and to community groups. She is an excellent communicator and is a very experienced manager of complex projects. Her style is to be highly inclusive, and to have very open and honest communication style. She is committed to maximising staff development within the research group and the client organisation. She works with a view to ensuring that when the research team "leaves" there is sufficient capacity, commitment and ownership within the organisation for the project to continue and flourish. She maintains relationships with the projects and clients she has been involved with – and checks up to see if the project is continuing to deliver.

She has presented the results of this project to US audiences. She spent a day at San Mateo County (California) where she talked informally to frontline social workers and presented her research to officials at the County level. The feedback from that was that a similar project could be implemented in a US County setting – and this is partly what has precipitated the present proposal.

In summary, the team has had considerable experience with the development and implementation of risk stratification tools. The development of the algorithms are relatively straightforward. Successfully implementing PRM within a complex health and human services setting is much harder. There are multiple agencies and professionals involved. Ethical, equity and privacy issues are at the forefront of concerns. Moreover, even if a PRM is successfully made available there is no guarantee that it will have any impact on practice. The experience of this research team lies with developing strategies to ensure that these tools are actually used. We have both the depth of scientific knowledge and practical experience to ensure that the research results transition into practice and practice into benefit for children.

Lessons on the Successful Deployment of Predictive Risk Models

The lessons we have learned from the successful deployment of the predictive risk model which we bring to the present project are:

- Predictive risk models involve much more than simply finding an accurate algorithm. Many accurate algorithms and computerised decision tools never get used because they fail to bring about changes to the practical decision-making and behaviour of professionals in the relevant fields.

- Engagement and governance by groups of end-users from multiple agencies if necessary at the commencement of a project is vital so that the tool is seen as

useful by front-line staff from the outset, and is not dismissed as yet "another" IT solution for a problem they didn't have.

- It is necessary to gain sufficient in-house commitment from the lead agency (DHS) to enable them to collaborate in the project, rather than taking the attitude that they have "outsourced" the whole project to an external team. This approach would enable the tool(s) to be embedded in the policy and practice of Allegheny County DHS. To attain its full value, employment of the tool will have to be maximised over a number of years, well beyond the time frame of the 12 month contract. For lasting impact, DHS commitment is key.

- IT staff from the data-warehouse must be allocated explicitly to work in liaison with the project team – especially the Software development team. The 12 month contract makes this a fairly tight time-frame.

- The research team must be willing to engage with, and hand over ownership to, those frontline managers, professionals and NGO groups who are critical to implementation.

- A shared understanding about the limitations (as well as the strengths) of these types of predictive risk models is needed.

- Sufficient engagement with legislators and political leaders is required.

Collaborative projects on which your organization worked, naming partner organizations.

All Predictive Risk Models have been developed in close collaboration with a variety of partner organisations. In the case of the Auckland hospitalisation risk models, we worked closely with all three Auckland regional hospitals (Waitemata District Health Board, Counties Manukau Health Board, Auckland District Health Board,) as well as the Nelson Marlborough District Health Board and family physician groups (Procare). For the child maltreatment PRM the collaboration was directly with the relevant government department (Ministry of Social Development).

Rhema is experienced in working with Government agencies, having worked with public sector organisation in the UK (South-Central NHS where she evaluated their leadership program for health professionals), Australia (She was on the medical specialist advisory committee of the Department of Health and Ageing), New Zealand (various hospitals and the Ministry of Social Development) and Singapore (KPTH a public hospital).

Describe the way your organization or collaboration would manage the process of working with DHS to design and implement decision support tools and predictive analytics.

The administrative part of the project (legal issues, billing, and contract negotiations) will be managed by Tom Davidson who is the business development manager for AUTEL. He will be the first point of contact for legal, billing and contract issues. Tom has considerable experience in business development and management both in New Zealand and the US. Tom has an MBA from Chicago Booth and has worked across the US and New Zealand in a number of business ventures.

Rhema Vaithianathan is the main point of contact within the research team. The DHS would be regularly briefed by her at every stage the project, to ensure that we are maximising value to the DHS (and partners). DHS would have to provide us with someone who is "dedicated" to the project. The DHS staff member would have to be able champion the project within the DHS and ideally be a part of the project team. Rhema operates a "continuous disclosure" policy where she alerts DHS to unexpected issues as they arise (rather than waiting for pre-specified reporting dates). Rhema will take overall responsibility for ensuring that the project delivers benefit and impact for the DHS – and ultimately improves outcomes for the children of Allegheny County.

Tim Maloney is the main econometrics expert. He has the technical expertise in the methods of predictive risk modelling. He and Rhema have been working together implementing predictive risk modelling. He has a PhD from Wisconsin, and having started his research career in the US and has a great deal of familiarity with the US system.

We also have a US based researcher involved in the project— Assistant Professor Emily Putnam-Hornstein. Emily has been working with the team on the New Zealand maltreatment project and has an excellent working relationship with the team members. She was an integral part of the Maltreatment PRM project. She has an intimate familiarity with the US CPS system, and is currently co-director of the Californian Children's Data Network.

In our experience, for a project such as this to have an impact on outcomes we would need commitment from the DHS to be a full partner at every stage. We would expect the DHS to assign at least one staff member to the project. An ideal candidate would be a policy expert who has been on the staff for some time, and therefore has a wide range of contacts, both within the DHS itself and its partner organisations.

We intend to employ a consultant based in to Pittsburgh. We have a contact at the University of Pittsburgh School of Social Work – and ideally we would be looking for a post-graduate trained social worker with good links to Allegheny County child protection agencies and a strong interest in racial disparities. We intend to appoint this person in

consultation with the DHS. He or she would function as a local resource for the team – for example he or she would organise meetings, deliver presentations to local interest groups, and so on. We would expect that as the project proceeded to implementation, a slide pack would be developed and delivered to frontline staff (social workers, Health Start providers, county officials, child welfare interest groups, minority group advocates., etc.) at local offices.

In our experience a crucial part of successful implementation is to ensure that the tool addresses the core issue of racial disparities. There is an ever-present danger that tools developed using historical data patterns will embed historical racial disparities. Given that African American and Native American children are more likely than their counterparts to be removed from their families and placed in foster care, remain in care longer and are less likely to exit foster care, the whole team will take a keen interest in the impact of the tool on racial disparities. We would want to address this with a variety of strategies. One is to ensure that together with DHS we set up a governance group with African American and Native American representation. This group would be engaged *right at the start* and in a meaningful way.

We would also want to ensure that we have consulted across a wide range of both frontline staff and researchers specifically from African American communities. We have allowed in the budget the cost of commissioning a review from a US based racial disparities expert so as to determine whether the proposed tool inadvertently risks negative impacts for people of colour, and how such risks may be mitigated. Rhema has a long-standing interest in disparities in New Zealand, and has co-authored a report with Māori researchers on the potential costs and benefits for Māori of implementing a Maltreatment related risk model in New Zealand.

We also have the opportunity to supplement the team with an econometrician and health economist, Professor Sarah Baird, who is based at George Washington University. Sarah is familiar with the techniques and methods of risk modelling. She is currently working closely with the New Zealand team, analysing the integrated child data to evaluate the impact of home visiting programs on maltreatment outcomes (this is an ongoing research program). While it is not intended that she will be an active participant in this project, she has technical knowledge of predictive risk modelling and understanding of integrated administrative data sets, and being only a 1 hour flight away would be able to come at short notice to provide presentation and technical advice. In our experience, there is a need for such a capacity. For example, if an important county committee had free time in their agenda and we wanted to opportunistically update them on the project, then it would be valuable to have a technical expert who understand the project in close proximity to Pittsburgh. Sarah's availability, her knowledge of the project and her close relationship with the research team would leave her well-placed to present at such a meeting

We realises that time-frames shift over the life of a project. Since the team members appreciate the value of impact as well as outputs, we are willing to change the timing and deliverables in the middle of a project if an opportunity arises for the project to feed into DHS priorities. For example, when developing a child maltreatment predictive risk model for

the Ministry of Social Development, we fast-tracked the project because an unexpected opportunity arose when we learned that the ministry was developing a White Paper. This was a major policy-position paper, and while initially our project was on a different time-frame, our willingness to expedite the analysis meant that our project could be incorporated into a wider policy. Our willingness to work in with changing organisational priorities and time-frames meant that this project – which was initially more research focussed – became an implementable program of work.

While it is not directly part of the current proposal, we have raised the possibility with the New Zealand ministries of organising a study tour for US officials and researchers to come to New Zealand and talk to the agencies and frontline staff who are using PRM in the health care and CPS contexts. Therefore, we believe this project will enable Allegheny County to be part of a national and international network of health and human service agencies who are at the forefront of using integrated data to intervene early and effectively in children's lives. The development of the analytical model does not require onsite presence. However, once the model is put into the field, it is crucial that the scientists are available to support the efforts of the governance groups and DHS in socialising the model. We would expect to visit a number of times and also be available via (US) phone at other times.

The field of predictive analytics in health and human services is littered with highly accurate models that have never been deployed. Going by our experience, for the project to avoid such a fate and have a long term impact, these conditions must be met. (1) A good relationship with the DHS must be maintained. (2) A strong governance group which includes members from the DHS and frontline people is needed to oversee the project, and (3) A reasonable degree of IT-capability within the organisation implementing the risk model is necessary. A good example is a recent experiment with the New York City CPS data where a model which would prioritise children for investigation was developed but never used.

Frontline workers may oppose predictive risk models because they fear their own professional judgement is being thwarted. My own experience with early users of PRM in England revealed a loss of fidelity to the model when frontline staff came under pressure to accept low –scoring patients, which of-course undermined the model as a tool for prioritisation. Moreover, models are sometimes developed by private sector companies more interested in the short-term take-up of the model than its ongoing integration into practice.

To prevent such attrition, organisational, leadership and culture change is necessary – and in health and human service organisations such change taken more than the 12 months to effect. Since for the project team, this proposal is part of their ongoing research program, their role is to support the necessary change over the longer time period.

We therefore believe that while we might not be physically located in the area, our willingness and desire to engage with this project over a long term increases the possibility that the project will have long term impact.

Meeting M/W/DBE Goals

As outlined above – the team is very committed to reducing racial disparities. Therefore, we will look specifically to sub-contract a African American researcher to undertake a review of the tool from a racial disparities point of view. For the Pittsburgh based project manager we will be favouring a suitably qualified African American contractor.

Describe your experience or approach to working with an existing IT vendor to implement/integrate solutions.

In general we have worked with the IT departments of the organisations who have generated the risk scores to create the risk reports. We have had some experience with taking on more of the coding, having had one of our PhD students work closely with a small rural hospital to code the risk scores onto the client's database management programs. In this case the hospital's staff did not have the level of IT skills the task required. In this project we provide the possibility of sub-contracting to a small boutique health software company who will offer the DHS the option of developing a customised software interface that will allow the risk score to be presented to various agencies and professionals at different levels of detail.

Project Description

We envisage this project will be completed in a number of phases. Each components of the project has been priced out separately so that DHS can decide which components if any to contract. Pricing is in USD and is based on the contract being held by AUTel or its subsidiary.

	Research and analytics (Vaithianathan et al)	*Software Design and Build* (Erudite Software)
Stage I: Generating the Options for Implementing a PRM to identify children at risk of adverse outcomes from the child welfare system	**Report** describing feasible options (what will be predicted, when will the score be deployed, who will have access to the score, what services will be deployed, barriers to take up, ethical issues and impact on disparities). **Meetings, Workshop and Presentations by Research team (x2)** with DHS staff, frontline professionals, outside agencies about	**Report** on the options from software implementation view including legal issue, protocols, security mechanisms to be used at the data-warehouse and end-users' systems to ensure timely risk scores can be generated and interrogated by professionals. **Specification** of tool:

	option(s) for implementing a PRM. **Data Specification** to describe the data that will be required from the data warehouse to develop the algorithm. **Integration** (with MOU if required) with other projects contracted under this RFP and (e.g. other contracts under this RFQ or Title IV-E Waiver Demonstration Projects)	functionality, system and interface design.
Cost	**$ 83,812.44**	**$ 42,500.00**
Stage II: Developing up to three Algorithm(s) to automatically identify children at risk of adverse outcomes at various points in their interaction with one agency (CPS)	**IRB approval** **Algorithm(s)** developed and validated using methodology specified in Vaithianathan (2013). **Report and slide pack** on key findings including prognostic strength of models, business cases for prevention developed from the model. **Report** by **racial disparities** expert on implication of the tool for improving or worsening disparities **Sub-contracts** with local expertise (Pittsburgh and Washington DC) available for on-site presentations and	Up to **three predictive analytics decision tools built** where risk scores are generated in real time and made available to appropriately credentialed professional staff via existing systems (e.g. KIDS). **Tool build, testing** and delivery to DHS to be deployed at various points in the welfare system. **User manuals** and other documentation (including code) *Note:* User-interface yet to be determined.

	meetings as required. **Development** of governance groups. **Workshops and Presentations** to key decision-makers, stake-holders, frontline professionals, NGOs, other public agencies, advocacy groups and legislators. **Testing and Validation** of the prognostic performance of all algorithms in the field as used by end-users at test sites.	
Cost	$ 195,562.3	$ 170,000.00
Stage III: Capability to generate reports which track trends, outcomes and enable monitoring of providers using risk scores	Developing **analytic reporting capability and data visualization** (e.g. tracking the average risk-profile of children in contact with welfare services, outcomes over time for selected risk groups).	Develop user interface for report-generating capability at agency level.
Cost	$ 41,650.00	$42,500.00

Table 1: Key components and price of each component

The **grand total is $ 576,024.** However, if DHS only wants to contract for parts of our proposal the cost will vary accordingly.

- If the DHS wanted to use its in-house IT capacity to generate the risk score (which many of our previous clients have done), and wanted to simply purchase the

research and analysis, then the price would be **$279,374** for consultation, research and analysis for stages 1 and 2.

- If the software component was also required, then the price would be **$491,874** and the DHS would receive a validated and tested risk scoring tool which with computer interface which could be deployed at (up to) three points in a child's interaction with welfare services. The tool would be made available to frontline professionals who are credentialed to access CPS information systems.
- For an additional costs of **$42,500**, employees of another agency (e.g. public hospitals) who are not credentialed for access to CPS data systems could be credentialed to access the risk score.

Stage 1: Developing the Options for Implementing a PRM for Children in (or at risk of) Contact with Welfare Services

The main goals of the project are to prevent poor outcomes for children under the care of child welfare by early prediction of these poor outcomes, and deploying "preventive" services early and with sufficient intensity to avoid the adverse outcomes. As in all PRM tools, the particular outcome (or a suitable proxy) needs to be recorded in the administrative data. There also need to be evidence based and adequately resourced preventive services (e.g. a home visiting program or a hospital based head injury education program) available in a timely fashion, following the identification of the child. Before rushing into a particular PRM project we need to consider the following:

(1) The point in the welfare pathway (e.g. at first intake, at police call out, at first foster placement, at first reunification) at which the risk score is generated. The critical point needs to be early enough to be useful, but also at a point where a non-stigmatising and well-resourced service is available to be deployed.
(2) The services that are available to be deployed in response to the risk score.
(3) What other options currently exist, apart from these services.

To answer the above questions we will map out the pathways through services for children through the County data system. The map will identify when the child is in contact with services and therefore the points at which a risk tool could practically be deployed.

We can then provide DHS with an *Options for PRM* paper which sets out where a PRM could be deployed , what outcomes could be predicted, and what services could be deployed at this point. This would also consider the broader ethical or potential legal risks of each option.

Some of the adverse outcomes we would look at include : (1) welfare placement disruption; (2) time of reunification; (3) the probability of reunification within a fixed time (e.g. six

months); (4) the probability of stable reunification; (5) the probability of *crossing over* into the juvenile justice system ; (6) the probability of mental health service utilisation;(7) the probability of mental health diagnosis; (8) the probability of a substantiated finding of physical abuse/ behavioural difficulties; (9) the probability of case closure. We would explore the degree to which all such outcomes are congruent. In our work of predicting substantiated maltreatment in New Zealand we found that there was considerable concordance between children at risk of different types of maltreatment (physical, neglect) with the *same* children being identified as high risk by our model. (Risk of sexual abuse was slightly different).

This *Options* Paper will then be presented to frontline professionals, managers and other end-users as identified by DHS. We would envisage a 1/2 day workshop to work through all the options and "round-table" them. Professor Vaithianathan was invited by San Mateo County in February to talk to its frontline social workers and managers and found that after a few hours' discussion they were able to come to some common understanding of the point at which such tools would be most useful (and therefore used) by frontline social workers and managers. It would also be useful to include local child-welfare advocacy groups and minority representations as part of the project's oversight group. We will also present the options specifically to a group of experts and advocates for African American children in welfare.

Key Tasks and Deliverables:

Research and Analytics:

(i) An *Options Paper* (a slide pack and short report) detailing the current critical pathways for children shown by the integrated data, and the points at which a PRM tool could be deployed to prioritise families and children for services. Discussion of outcomes that would be predicted and services that would be deployed in response to the risk scores.

(ii) Specific consultation program with interest groups in improving outcomes for African American children.

(iii) Workshops with key decision-makers and frontline users to go through the options and consider their feedback.

(iv) Report to DHS on the feedback and seek agreement about (i) outcomes to be predicted; (ii) points at which the tool will be deployed; and (iii) professionals and service providers who will be expected to engage with the risk score.

Software Development Team:

(i) Outline of design for each of the options and feasibility of implementing the risk tool on existing systems within the contracted time-frame.

Stage 2: Developing and Validating the Algorithm(s), Building the Risk Scoring Tool, Integrating the tool into existing IT systems, Fields Testing.

Research and Analysis

Once we have agreed on the set of outcomes that we are most interested in predicting and the point at which the risk model will be deployed, we will work with Erudite Software analysts (or in house IT team) to enable them to understand the type of data that will be available to the algorithms when it is run off "live data". Although the algorithm is implemented from live data, it is developed using historic data that is retrieved from the data warehouse. Therefore, the next step to developing the algorithms is to determine a data specification which tells DHS what data will be required for the algorithm development. This data request will include the variables and the format. The specification will be developed in consultation with the data expertise within the DHS. At this stage we will develop the statistical methodology and apply for IRB approval to undertake the research (we envisage that a New Zealand IRB process will be acceptable).

Fields that would lead to easy identification such as names and social security numbers would be eliminated from the data used. However we will need birth dates, dates at which they accessed various services, and residential zip codes since these are crucial to accurately predicting outcomes. This means that the data will be subject to HIPPA but will be termed a *limited dataset*. We will therefore have to establish a data user agreement between the research team and DHS. Our practice has been to maintain the data on a single stand-alone locked computer at the University with no external drives, to have unique logins for the data users and to use a data destruction program at the end of the project. Our department has a secure data-lab space that is accredited by the New Zealand Statistics Department. This space has a locked door, and authorised entry to the computers. The computers have disabled external drives and are unable to print. This space would be ideal to store the data. Transfer of the data from DHS to AUT will take place via an FTP with an encrypted zip file. The password for the file will be sent separately (via SMS). We will undertake the analysis and development of the models using SAS and STATA software. We will use logistic regressions for developing the model. We have found that this is preferable to neural networks because the risk factors are more intuitive. The final model will have to trade-off between being intuitively reasonable and therefore having higher acceptance amongst users, with accuracy. In terms of accuracy, we rely on a range of prognostic tests (area under the ROC, PPV, p-values of each variable). We utilise a split sample approach for validation (see Vaithianathan et al (2013) of methodology. Once we have developed the prototype algorithms we will bring the oversight group together for an initial feed-back session.

Software Development Team

Our approach is to build a tool that is external to existing data storage mechanisms, which holds no data initially but acts as a conduit, so as to produce a risk score using the Warehouse data, which is then delivered to the agency system (such as KIDS). This method allows credentials to be at a system level rather than an individual level and also allows

integration with existing mechanisms. This approach is believed to have a higher probability of acceptance among existing users and low risk of any security issues. The software team works closely with the researcher to design an implementation methodology for the risk score calculations, so that they may be modified without coding changes by the software development team, but do not interfere with the program's efficiency in calculating live scores. The software team also works closely with the data warehouse governance group to ensure that all legal requirements and standards are adhered to in data extraction methods and protocols. Each agency that becomes part of the system will be incorporated as an individual project, and the software team will work with a governance group from the agency to establish the methods and protocols for requests, and the delivery of the risk score to their system. Ideally this will be a system-to-system transaction and all credentials will be handled in the request and the delivery.

Key Tasks and Deliverables:

Research and Analytics

(i) Data specified and transferred to research team, methodology for developing algorithm identified and IRB approval obtained.
(ii) Algorithm(s) developed and validated using methodology specified in Vaithianathan (2013).
(iii) Report and slide pack on key findings, including the prognostic strength of models and business cases for prevention developed from the model. (see Vaithianathan (2012) for an example of the type of report that will be generated at this stage).
(iv) Presentation of results for key decision-makers, frontline professionals and other agencies.
(v) Prototype software designed to implement the tool and user feedback on the designs.
(vi) Report on the potential positive and negative impact of the tool's use on racial disparities in outcomes.

Software Development

(i) Design of the risk score methodology to ensure a pass-through operation with performance and researcher maintainability of the algorithms. Done in collaboration with the research team.
(ii) Design of protocols and methods of data extraction from data warehouse. This is done in collaboration with the data warehouse team to ensure all legal and compliance standards are met.
(iii) Design of protocols and methods of request and score delivery to and from agency systems. This is done in collaboration with the agency teams to ensure all legal and compliance standards are met.

(iv) Build of software tool prototype to meet the above standards. Testing to take place under controlled conditions.

Stage 3: Implementing a Report Tool

One of the key features of risk scoring is that it can used to learn about the efficacy of programs, the pathways of children through welfare services and the related outcomes. In Stage 3 we propose to build an analytic tool that will allow users to visualize the risk scored data together with other critical variables from the integrated data that will allow tracking, monitoring and policy analysis.

Examples of reporting capabilities would include:

- Visualizing a suite of outcomes (average time in foster care, stability of foster care, family reunification, behaviour problems, poly-pharmacy, physical abuse findings, residential stability) tracked over time for children grouped by risk, class and important demographic variables (race, age at entry to welfare services, zip code) which enables researchers to look at the success of services for sub-groups;
- Comparing outcomes and trajectories for children of similar risk scores but who were offered different preventive and support services.
- Track the source of risk over time – which of the predictive variables are most important and whether or not they changing over time and across sub-populations.
- Drilling down to individual families. A caseworker might be able to drill down in his or her own case, and have a set of "comparator cases" matched on risk scores that are automatically generated. These anonymised comparator cases will be compared to the caseworkers cases to provide evidence of outcome differences between case workers' cases and comparator groups.

Stage 4: Maintaining and Enhancing the Tools in Years 2 to 5 (Out of scope)

Professor Vaithianathan and the team are willing and able to return at regular times to check on the implementation of the project and refresh the algorithm if necessary. We will also be available to support any external party who would be contracted to evaluate the impact of the predictive risk model on outcomes. We will also be available to champion the tool in research forums, and would hope to publish the results of this research project in academic journals.

Staffing Plan

Professor Rhema Vaithianathan: Will be responsible for the overall project and will be the main liaison with the DHS. She will do the presentations, workshops and consult with the governance groups. She will be the main author of the final report. **Professor Tim Maloney and Dr Nan Jiang** will undertake the statistical analysis, and be responsible for data security. Professor Maloney is an applied economist who has extensive experience working with administrative data. Dr Jiang has developing predictive risk models for hospitals.
Dr Irene De Haan was part of the team who worked on the New Zealand Child maltreatment project. She will bring her expertise in child welfare and preventive services to the team. Dr **Emily Putnam-Hornstein** has an extensive knowledge of child welfare services and the use of linked data within the US context. **Murray Polson (Erudite Software Ltd.)** will lead the design phase of the project and his staff will undertake all development. Murray is a mathematician by training and has worked in software development for over thirty years, being involved in some of this country's largest and most innovative projects. For the past decade Murray has specialised in health analytics for a range of private and public organisations.

Time Line (for Research Team):

The start of the contract is in September 2014. The length of the contract is 12 months.
August (pre-contract)

- Team meetings with DHS staff and diarising of key meeting dates.

September (2014):

- Initial Meeting of team in Pittsburgh
- Meetings and presentations with (1) user/manager groups; (2) Child welfare and minority representatives.
- Background research on developing options for predictive risk modelling in Allegheny County.
- Establishment of governance and design group from the data warehouse to enable requirements for legal, standards and security to be identified.
- Establishment of governance and design group from the agency to enable requirements for legal, standards and security to be identified.
- Research requirements that need to be met.
- Concept design of tool in collaboration with research team.

October (2014)

- Design of interface specifications for data warehouse.
- Design of request and score delivery specifications for agencies.
- Design of core tool for risk score calculation.

November (2014) – January (2015):

- Presentation of *Options Paper* for the deployment of a risk tool to reduce adverse outcomes for children in welfare services. This report would include outcomes to be predicted, points in the welfare pathway where the tool will be deployed, and ways of responding to risk scores).
- Discussion with legislators and senior administrators.

- Seeking common county-wide, multi-agency agreement on the model(s) that will be developed.
- On acceptance of design, delivery timetable to be created with testing milestones.
- Software team for testing and acceptance of individual modules to be formed.
- Software build commences
- Software Component delivery and testing.

January – May (2015):

- Development of the algorithm, testing and validation.
- Implementing the algorithms that have been shown to be sufficiently accurate.
- Working closely with the DHS IT team to implement the algorithm incorporating the live feed data
- Validation of the risk prediction based on the live data.
- Risk Score generated and distributed to trial sites and end-users.
- Reporting Tool Specification.

May (2015):

- Reporting Tool delivery time line.
- Start building the reporting tool.

July (2015):

- Final report, slide pack and top line report on the project, with recommendations for the next steps including ongoing validation, and procedures for refreshing the algorithm.
- Final software package and user-manuals delivered.

August – September (2015)

- Contingency and slippage time.
- <User training - currently out of scope>

Strengths of the Project and the Research Team

The Project

The core strengths of the project lie with the efficacy of our model and interface it provides between the predictive algorithm used and the frontline staff working with actual cases. As such, it will serve as a tool for culture change at the "coalface" for those working with at-risk children, and of course to the advantage of the children themselves. Its use of suitable selected oversight groups serves to safe-guard against the possibility of demographic disparities undermining the program's positive intention, while the ongoing availability of the team will serve to fully incorporate the model into frontline practice. The use of computer-generated algorithms provides the basis for a far more reliable measure of success or failure than the intuitions and anecdotal evidence of frontline staff by themselves. Our three- stage pricing allows for flexibility – a DHS, for example, need only

purchase those parts of the program that it needs. Moreover, the program is based on models that have proved successful, such as the model, outlined above, for predicting hospital readmissions, which is now being used across the whole Auckland region. The methodology upon which the project is based has also been tested by the work we have done in New Zealand toward the production of a ministerial white paper on vulnerable children.

The Research Team

Professor Vaithianathan, the team's leader, has implemented predictive risk models in a range of contexts. She has worked closely with various agencies, sustaining her engagement and leadership to the point of ensuring that the PRMs were not only adopted but also successfully implemented. One such example is the implementation, under her guidance, of the model she developed for predicting hospital readmission, outlined above. She has also collaborated successfully with the New Zealand Ministry of Social Development, as part of her research for, and contribution to, its 2012 white paper on vulnerable children. The individual capabilities of team members are briefly outlined above. Broadly, they are a capable and enthusiastic group of people who have worked together before and who work very well together. Between them they have a range of skills that cover all aspects of the program, including IT expertise, proven research skills and practical frontline knowledge.

Resumes of Core Research Team

Rhema Vaithianathan is Professor of Economics at Auckland University of Technology and a Senior Research Fellow at Singapore Management University. She is a health economists and has undertaken research in Australia, New Zealand, Singapore, UK and US. She has published extensively in health economics as was awarded a 2007 Harkness Fellowship at Harvard. She is implementing major predictive risk modelling projects in New Zealand and Singapore including working with the New Zealand Government on developing a predictive risk model that would result in every child born in New Zealand will be "risk scored" according to the likelihood that they will be maltreated by age 5. This work was reported in the *American Journal of Preventive Medicine.* Professor Vaithianathan is an advocate for translational research in economics, taking research from the journals and classrooms to the people who matter. She received a Phd in economics from the University of Auckland.

Tim Maloney is Professor of Economics and Chair at Auckland University of Technology. He is a labour econometrician who specialises in the analysis of administrative data. He has held positions at University of Missouri, Bowdin College and the University of Auckland. He has most recently worked on predictive risk models which can risk score students as they enter college to identify those who are at greatest risk of non-completion. He has also worked with Professor Vaithianathan on the predictive modelling of maltreatment risk for the New Zealand Government. Tim has a PhD from the University of Wisconsin-Madison.

Emily Putnam Hornstein is an Assistant Professor in Social Work at the University of Southern California. With an interest in child maltreatment, public child welfare systems, and extensive experience in administrative data analysis, Putnam-Hornstein's current research focuses on the application of epidemiological methods to improve the surveillance of non-fatal and fatal child abuse and neglect. Putnam-Hornstein's dissertation, funded by the Harry Frank Guggenheim Foundation, involved the linkage of 4.3 million birth records to more than 500,000 child protective service records and 25,000 death records from California. Analysis of this repository has generated knowledge as to where scarce child welfare resources may be most effectively targeted and advances an understanding of maltreated children within a broader, population-level context. Putnam-Hornstein was a member of the research team which worked on the predictive modelling of maltreatment risk in New Zealand children. Putnam-Hornstein has a PhD from University of California at Berkeley.

Irene De Haan is as lecturer (Assistant Professor) in Social Work at the University of Auckland. She had a long career in social work prior to becoming a researcher. For 15 years she managed an NGO which worked with a family strengths-based model of social work practice. She also worked for the office of the Chief Social Worker in a policy role. Her research focuses on prevention of family violence and child maltreatment and on early intervention. She currently chairs the National Family Violence Death Review Panels which undertake thorough analysis of professional practice in situations where someone is killed as a result of family violence. Irene was part of the team who worked on modelling maltreatment risk in New Zealand children. Irene has a PhD in Social Policy and Social Work from Massey University

Nan Jiang is a Lecturer (Assistant Professor) at the Auckland University of Technology. She is an applied economist who has expertise is analysis of large and complex data sets. She has worked closely with Vaithianathan in developing and implementing predictive risk models in health care. Jiang has a PhD from the University of Auckland.

References

Referee for PRM in Child Welfare (Vaithianathan, Jiang, Maloney, De-Haan, Putnam-Hornstein)

Moira Wilson,
Senior Analyst
Ministry of Social Development
New Zealand
[redacted]

Referee for PRM in Hospital Services (Vaithianathan and Jiang)

Dr Harley Aish

Family Physician and Chair of Greater Auckland Health Integrated Network who over-saw the implementation of PRM for hospitals

[redacted]

Referee for Professor Tim Maloney

Dr Grant Scobie

Principal Advisor
The Treasury
New Zealand
[redacted]

Selected Publications by Research Team

Vaithianathan, R., Maloney, T., Putnam-Hornstein, E., & Jiang, N. (2013). Children in the public benefit system at risk of maltreatment: Identification via predictive modelling. *American journal of preventive medicine*, *45*(3), 354-359.

Vaithianathan, R, Dare T, Maloney T, Jiang N, De Haan I, Dale C, **Putnam-Horstein E**. (2012). *Vulnerable Children: Can administrative data be used to identify children at risk of adverse outcomes?* Wellington: Ministry of Social Development.

Putnam-Hornstein, Emily, Barbara Needell, and Anne E. Rhodes. "Understanding risk and protective factors for child maltreatment: The value of integrated, population-based data." *Child abuse & neglect* 37, no. 2 (2013): 116-119.

Putnam-Hornstein, Emily, and Barbara Needell. "Predictors of child protective service contact between birth and age five: An examination of California's 2002 birth cohort." *Children and Youth Services Review* 33, no. 8 (2011): 1337-1344.

de Haan, I. & Connolly, M. (in press). Another Pandora's box? Some pros and cons of predictive risk modelling. *Children & Youth Services Review.*

Panattoni, L. E., **Vaithianathan, R.**, Ashton, T., & Lewis, G. H. (2011). Predictive risk modelling in health: options for New Zealand and Australia. *Australian Health Review*, *35*(1), 45-51.

Lewis, Geraint, Heather Kirkham, Ian Duncan, and **Rhema Vaithianathan**. "How Health Systems Could Avert 'Triple Fail' Events That Are Harmful, Are Costly, And Result In Poor Patient Satisfaction." *Health Affairs* 32, no. 4 (2013): 669-676.

Vaithianathan, Rhema, Nan Jiang, and Toni Ashton. *A Model for Predicting Readmission Risk in New Zealand*. No. 2012-02. 2012.

Lewis, Geraint, Martin Bardsley, **Rhema Vaithianathan**, Adam Steventon, Theo Georghiou, John Billings, and Jennifer Dixon. "Do 'virtual wards' reduce rates of unplanned hospital admissions, and at what cost? A research protocol using propensity matched controls." *International journal of integrated care* 11 (2011).

Lewis, Geraint, **Rhema Vaithianathan**, Lorraine Wright, Mary R. Brice, Paul Lovell, Seth Rankin, and Martin Bardsley. "Integrating care for high-risk patients in England using the virtual ward model: lessons in the process of care integration from three case sites." *International journal of integrated care* 13 (2013).

Budget Narrative

Description	***Researchers***	**Research Costs**	**Software Costs**	***Notes*** ***Please note that this is a fixed price proposal, and the time/daily rates are indicative only***
		STAGE 1		
Initial meetings with county staff, key decision-makers, frontline staff, preparation of "Options" report	EPH; RV; TM; ID and Pittsburgh based researcher	$ 43,472.60		*Approximately 49 days at an average of $895 per day*
Erudite Software Subcontract to outline systems designs for each option	Erudite		$ 42,500.00	
Travel,(sub) contract management, project management, computer hardware, library services, software (SAS, Stata), insurance, photocopying, facilities, HR , set up costs	AUTel	$ 40,339.84		*Includes travel for team to meet at Pittsburgh, travel for meetings, second workshop session to go through options.*
STAGE 1 TOTAL		$ 83,812.44		
		STAGE 2		

IRB application, establishing data specification, Developing algorithm(s), presentation of results, report on final algorithm(s), Analysis and Literature Review, Ethical Issues	EPH; RV; TM; NJ and Pittsburgh based researcher	$ 136,762.36		*117 days at $1168 per day. Higher charge out rate reflects the complexity of the data analysis.*
Sub Contract for Disparities Report	Disparities Researcher	$ 32,000.0		*Estimate based on similar report from disparities researchers on New Zealand project*
Sub contract for Erudite Software			$ 170,000.00	
Travel , contract management, project management ,computer hardware, library services, software (SAS, Stata), insurance, photocopying, secure data storage capability, facilities	AUTel (and contingency for Professor Baird if necessary)	$ 26,800.00		*Includes final wrap up presentation, and contingency for additional presentations if required.*
STAGE 2 TOTAL		**$ 195,562.36**	**$170,000**	
		STAGE 3		
Consulting with managers on desired functionality, Developing proto-type reports and analysis	TM; RV; NJ and Pittsburgh based researcher	$ 33,320.00		*38 days of researcher time at an average of $867 per day.*
Sub contract for Erudite Software			$ 42,500.00	
Travel , contract management, project management, computer hardware, library services, software (SAS, Stata), insurance, photocopying, secure data storage capability, facilities		$ 8,330.00		

STAGE 3 TOTAL		**$ 41,650.00**	**$ 42,500.00**	