

Affordability Assessment of Industrial Product-Service System in the Aerospace Defence Industry

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Abstract

The Industrial Product-Service System (IPS2) takes a whole life cycle view in order to consider the total cost of the IPS2 offering. This paper focuses on the concept of customer affordability which aims to review current practice in industry and with interaction between customer and solution providers to identify factors affecting affordability. It secures a standard definition and proposes a measurement technique called the Affordability Index (AI) within the aerospace defence industry. A preliminary Affordability Capability Audit Tool is developed to give an indication of the confidence level about the AI. It identifies challenges in industry and outlines opportunities for further research scope.

Keywords:

Product-Service System, Aerospace Defence Industry, Affordability Assessment, Affordability Index, Affordability Capability Tool.

1 INTRODUCTION

A Product-Service System (PSS) has been defined as 'a system of products, services, network partners and supporting infrastructure that is economically feasible, competitive and satisfies customer needs [1]. It offers dematerialised solutions that minimise the environmental impact of consumption'. A PSS consists of products and services which have tangible and intangible elements combined together to deliver value to the customer throughout its life cycle while ensuring economic profitability for the manufacturer.

It is important to ensure that the PSS offering is within the customer spending ability, hence the need for an investigation into the affordability assessment of PSS offerings. This paper focuses on current practices of affordability assessment and measurement of PSS offerings within the aerospace and defence industry, to help to decide whether the customer can afford to pay for a capability contract offered by the solution provider.

The paper is structured as follows:

Section 2 describes the research method and the design of the capability audit tool; section 3 presents the related research in the area of affordability and Industrial Product Service System (IPS2) contracts, or 'availability contracts' as these are sometimes known.

Section 4 examines current industrial practice and challenges in affordability prediction; section 5 explains the affordability capability audit tool development while Section 6 contains the discussion and conclusion with the limitation of the research and further research direction.

2. RESEARCH METHODOLOGY

2.1 Literature Review and Questionnaire

The methodology adopted in carrying out the research, is presented in Figure (1).

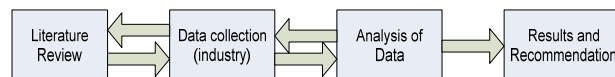


Figure 1: Research Method

A review of literature in the area of PSS, affordability and the defence and aerospace industry was carried out by consulting relevant journals and academic papers to gain an understanding of the subject areas. Research in affordability is relatively new both in academia and industry, and so the widest possible search was made to gather information from academic and industrial literature, both published and unpublished. The range of sources reviewed includes masters theses, textbooks, conference papers, doctoral dissertations, industry reports, and unpublished working papers. Databases like Compendex, Inspec, and Emerald were used in conducting the search as well as the Google™ search engine. This was necessary to gather existing definitions and measurement techniques in literature in order to be able to compare them to those being used in practice.

The literature review informed the design of a questionnaire to be used in conducting interviews. Data collection was performed in three organisations within the aerospace and defence industry. Two of these were suppliers of PSS solutions and the third was a major customer. This customer, UK Ministry of Defence (MoD),

has enough knowledge and experience of dealing with many solution providers across the industry. Therefore, data obtained from the customer is robust enough to depict the current practice in affordability. Some examples of questions asked during the interviews are as follows.

- (i) What is your understanding/definition of affordability?
- (ii) What factors drive/ affect your affordability?
- (iii) How does each factor weigh at the bidding stage?
- (iv) How is affordability predicted at the bidding stage?
- (v) How do you monitor the affordability of a project over the life cycle?

In the supplier organisations interviews were arranged with functional experts involved in each stage of the PSS lifecycle from bids and proposals through to in-service support. This included those responsible for the design of both the product element and support element of the PSS solution.

In the customer organisation interviews were arranged with functional experts involved with the appraisal and evaluation of individual of PSS offerings, the deployment of PSS solutions to the end-users, and portfolio planning /review of alternative PSS propositions against long term budgets.

Over 30 hours of interviews were conducted in total, typically in sessions of 60, 120, or 150 minutes. Topics in each session were grouped under relevant headings in order to achieve a logical structure. Verbal responses were captured through audio recording and hand-written notes. Where possible, examples of work products were collected.

Data from interviews was analysed using MindManager®. Mind maps produced by this tool helped in understanding the current practice in cost estimation and the use of qualitative and quantitative measures in affordability assessment.

The understanding of current practice in the organisations interviewed was compared with the observations from the literature review. A summary of outcomes was presented to each organisation for validation, the outcomes being recorded in the form of presentations and deliverable reports.

The outcomes included opportunities to improve current estimating practices in the organisations interviewed (e.g. based on ideas from the literature review), and opportunities to improve the qualitative and quantitative measures originally proposed for affordability assessment base (e.g. based on feedback from the organisations). The latter outcomes have the greater relevance to the work presented in this paper.

2.2. Affordability Capability Audit Development Process

The aerospace defence business environment differs from others, because it has fewer customers and more contractors. Contractors are invited to bid for a contract which would be awarded to a suitable contractor (prime contractor). Contracts could be awarded for different stages of the Concept Assessment Demonstration Manufacture In-service Disposal (CADMID) cycle (each could last over 10 years) or the whole CADMID. Due to the duration of availability/capability contracts, it is very difficult to make a good assessment of affordability along the CADMID or for some stages of the CADMID (this is further explained in the section 3.2). Also it is very important to know the factors that affect an availability or capability contract. Then the factors are weighted to know

how much impact they would have on affordability. This is a challenging task since the level of knowledge available at the bidding stage is usually low. It would be valuable for the bidding team to assess its capability to determine customer affordability. No method or technique was available in literature, but an excel-based tool was developed by the authors to assess the capability of the bidding team. This is called the Affordability Capability Audit Tool. The aim of the tool is to assess the capability of the bidding team in affordability prediction based on the level of information available about each of the qualitative and quantitative factors affecting affordability. The process followed in the development of the tool is described in figure (2).

First, it was necessary to identify a need which the tool would meet. Through interview sessions and workshops, industrial experts agreed that a capability audit tool would be useful for earlier stages of contracting.

Then the factors to be included in the tool were identified. After which a method of scoring was defined to be between 1 and 5, 1 being the lowest and 5, the highest. The next stages were to determine the elements that would enable the bidding team to provide the right score for each factor as well as the questions that would enable them assess each element.

The expected result of the tool was represented using Microsoft word. Then the tool itself was developed. Lastly, the tool was tested to see if it produced the desired result and this process was iterated until the desired result was achieved.

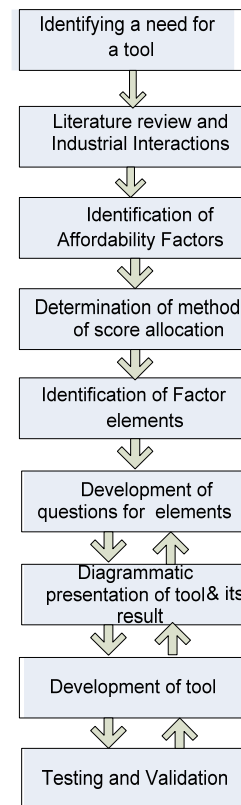


Figure 2: Affordability Capability Audit Tool development process

3. RELATED RESEARCH

3.1. Affordability Definition

Affordability is the 'degree to which the Whole Life Cycle Cost (WLCC) of an individual project or program is in consonance with the long range investment capability and evolving customer requirement' [1]. This is the definition developed by the Network of Excellence in Affordability

Engineering (NoE in AE) at Cranfield University. This definition is provided for the aerospace and defence industry and it emphasises the need for a correlation between the WLCC of defence projects and the financial ability of the customer not just to pay the acquisition cost when the contract has been awarded to industry, but across the project life which could last for 40 years or more.

It would be useful to consider the understanding of affordability in other sectors.

The Merriam-Webster Collegiate Dictionary explains the word 'afford' as managing 'to bear without serious detriment' [2]. Affordability has been described as the ability to bear the cost of something (software sector) [3]; a 'measure of whether housing can be afforded by certain groups of households' (construction sector) [4]; the provision of services which can be afforded by customers at different income levels (utility sector) [5]; the ability to procure a system as the need arises, within a budget, operate at a required performance level and maintain and support it within an allocated life-cycle budget (aerospace sector) [6]. It has been defined as the ability to secure a 'given standard of housing (or different standards) at a price or rent which does not impose, in the eyes of some

provided to the customer; hence it has the following features:

- A physical product core (e.g. aero engine) enhanced and customised by a mainly non-physical service shell (e.g. maintenance, training, operation, disposal)
- Relatively higher monetary value and importance of the physical IPS2 core, and
- A 'business to business' relationship between IPS2 solution providers and their customers [12].

The project life cycle is usually referred to as the CADMID lifecycle [13] as illustrated in figure (3). Within the aerospace defence industry, an IPS2 is typically characterised as an availability contract spanning the Manufacture and In-service phases of the UK MoD's CADMID. The customer's motivation in moving to availability/capability contracts is an improved assurance that the required functionality, performance, and availability will be reliably delivered by the solution provider over a contract duration which could be 40 years or more, and that this will be achieved within a cost profile which is affordable and consistent with the original estimates.

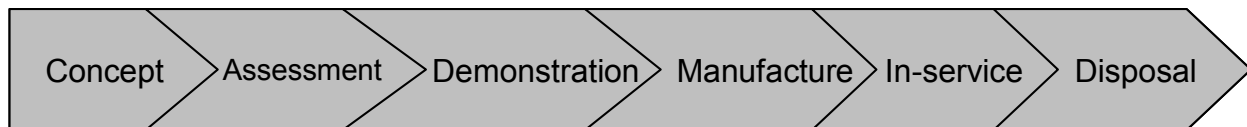


Figure 3: CADMID cycle of a typical defence availability contract [13]

third party (usually the government) an unreasonable burden on household incomes' (construction sector) [7]. As expressed above, the meaning and measure of affordability varies from one industry to another because their operational models and strategies for cost appropriation differ. However, two elements are commonly considered in these affordability definitions: customer budget or income and the cost of the product/service or IPS2 offering.

The standard definition adopted in this paper is the NoE in AE definition since this study focuses on the aerospace defence industry.

3.2. PSS/IPS2 and Availability Contracts

A PSS definition provided by [8] describes the concept of 'tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs'. Also the solution provider or prime contractor relies on a network of suppliers and service in order to deliver an integrated solution to the customers [9]. PSS has also been defined as a 'system of products, services, networks of "players" and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models' [10].

The key elements of a PSS are:

- Product: a tangible commodity manufactured to be sold. It can be used to fulfil the user's need.
- Service: an activity (work) done on a commercial basis for someone which has an economic value.
- System: a collection of elements including their relations [11].

The IPS2 concept provides an opportunity for the solution provider to develop innovative offerings by adding complementary services to the products and systems

This assurance is achieved by the transfer of risks from the customer to the solution provider, whereas the customer traditionally purchased 'spares and repairs' services on an open-ended 'as required' basis, they now purchase 'in-service support' for a fixed price.

The solution provider's motivation is that the customer will make a longer-term contractual commitment that justifies additional investment in people, processes, and facilities. This additional investment enables a transition from the purchase of individual products to that of services and system solutions which have the potential to reduce the environmental impacts of the customer's ad-hoc needs and wants [14].

The main concern is that the fixed price set by the solution provider for an availability contract can be raised sufficiently to cover its increased risk and maintain profitability whilst still being affordable for the customer.

This justifies the need to investigate the affordability of availability/capability contracts. It is important to note that 'capability' contracting is an objective within the aerospace and defence industry but, to date, relatively few capability contracts have been placed (e.g. on the basis of including more stages of the CADMID cycle, or more 'defence lines of development', within the scope of the contract). Currently, most contracts are availability contracts.

4. CURRENT INDUSTRIAL PRACTICE/CHALLENGES

4.1. Affordability Process

Interviews were conducted with functional experts in industry from one customer and two contractors within the aerospace defence industry. Findings revealed there is no uniform definition of affordability from both parties (customer and contractors), but both parties agreed that affordability related to a comparison between the customer budget and the WLCC of the project. The definition developed by NOE in AE at Cranfield University

was proposed and adopted as the standard definition of affordability.

The process of affordability assessment was described which was captured from the customer and presented in the flow chart in figure (5). Affordability prediction must be done at the bidding stage to inform the negotiations on the scope and price of a contract such that the customer knows if it has the financial strength to bear the burden of the contract, given the value the supplier is able to provide.

The process starts with a cost model (activity 1) being built by the customer which includes provisions made for risks. The estimate could be refined (activity 2) before being fed back to the Directorate Equipment Programme (DEP) who is responsible to the MoD Finance Director for the equipment plan. The Directorate Equipment Capability (DEC) is the equipment customer, also part of the DEP. DEP pull together the plan while the DEC manage the priorities and programme (activity 3). The refined estimates are then measured against top level budget (activity 4). Upon approval, solution providers from industry are invited to tender for the contract, otherwise the estimate needs to be refined (activity 5). At this stage the contract specification could be adjusted based on functionality, performance or availability

(activity 10). The financial controller is involved in the process of refining and adjusting the estimates. The customer seeks to build flexibility into the contract. Tenders proposed by industry are examined by the commercial team together with the cost estimate, cost implications of risk and the supply chain sustainability, and then an evaluation is made with the Master Data and Assumptions List (MDAL). After this, through life Value For Money (VFM) is assessed through investment appraisal and through life support till the disposal phase. These are also compared to in-house capability and the traditional types of contracts in order to make a good prediction of affordability (activity 6). In a single bid, the customer would investigate the solution provider's finances and require a level of detail during the evaluation process, while contractor's responses are compared in competitive bid. If the tender is suitable, the contract would be approved with negotiations within parameters (activity 7). When negotiating the contract with the solution provider, bottom up estimates are done to be able to reduce technical risk and reduce overall cost. The process is iterative in order to get the best solution for the customer. For example reduce availability from 99.9% to 99.5% to achieve cost saving. This negotiation would be taken back to the DEP for approval (activity 8). This leads to a full contract award, otherwise the whole process starts again (activity 9).

The affordability process represented in figure (4) is iterative depending on contract. The earlier stages of process are done internally before an invitation is sent to contractors in industry. This flow chart is more reflective of an individual project. It is useful to note that providing prices to the customer to support this sort of model normally requires a significant level of company effort and appropriate management approval/review.

Apart from the challenge of not having a uniform definition, key challenges identified within industry are as follows:

- There is no standard way of predicting or measuring affordability.
- There is a difference between the customer and the end-user. This is due to the fact that the customer is such a large organisation operating in different parts of the world. The procurement arm sources and

secures contracts to deliver the capability required by the end-user (a group of service men).

- The end-user has no view or opinion on affordability, but it can assess customer value in terms of performance. The end-user does not influence the budget allocation on each contract, hence it has no view of affordability. On the other hand, the contractor does not always know the end-user's view

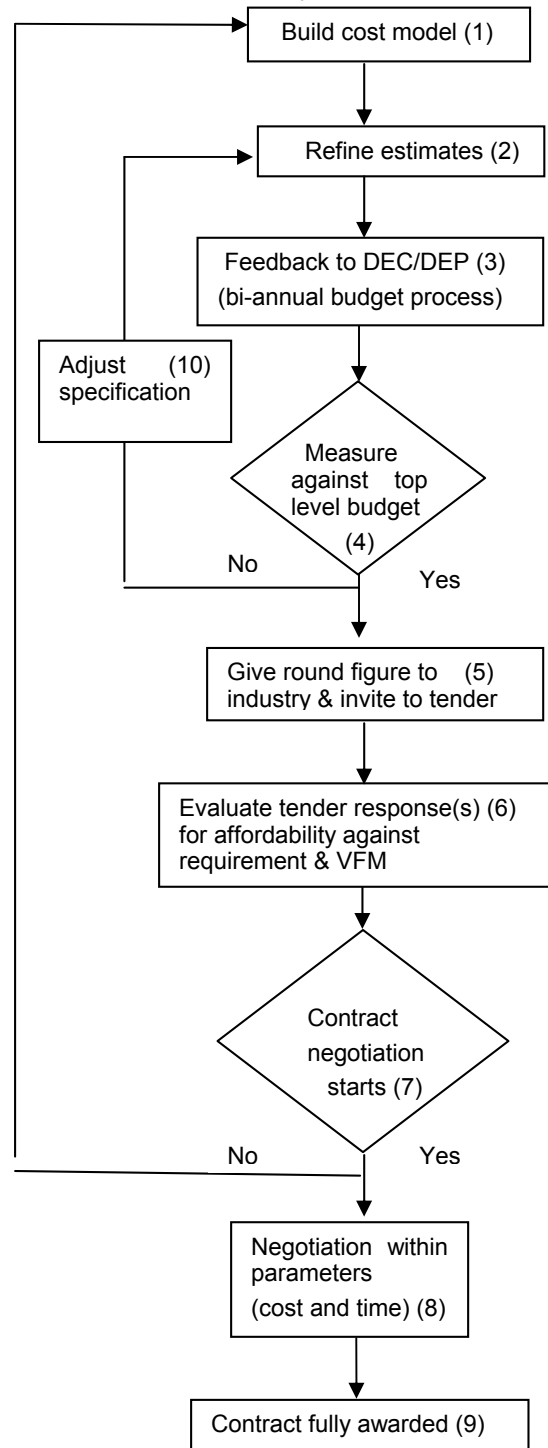


Figure 4: Affordability prediction process.

of customer value apart from the procurement arm's view which is based on financial judgement.

- Factors affecting Affordability include:
 - Change in requirement

- (ii) Competition
- (iii) Price
- (iv) Whole Life Cycle Cost
- (v) Budget constraints
- (vi) Suppliers
- (vii) Technology innovation
- (viii) Perceived quality
- (ix) Impact of regulations
- (x) Performance related measure

- Usually, the solution provider is only allowed visibility of individual projects, not a program (a combination of projects running parallel or consecutively). This means the contractor may be able to provide solutions that offer most value for money, within a program. A closer working relationship between both parties would allow a better understanding of customer's need and possible ways of achieving cost savings and good value for money across projects.
- Affordability is determined by the WLCC; hence the accuracy of initial cost estimates has a direct impact on customer affordability. A robust estimate would give a better indication of customer affordability. If the estimate is understated or overstated, it would provide a false indication of affordability.
- Where projects have a fixed price agreed by the customer and the contractor, the delivery of such projects could be affected by changes in the cost of resources across the project life cycle. Examples of these are labour rates, fuel price, cost of raw materials as well as other factors affecting the supply chain.

An understanding of the affordability process is useful in deriving the factors affecting affordability.

4.2. Affordability Prediction

Results from the interviews conducted with both customer and solution providers revealed that there are two major qualitative factors affecting affordability namely:

- CATS – Customer Available To Spend based on customer budget. This is the financial ability of the customer at program and project level
- WLCC – Whole Life Cycle Cost. This is the cost from concept stage to disposal; cradle to grave

Qualitative factors affecting affordability identified through literature review and interaction with the customer and solution providers are refined and represented in figure (5). These factors affect affordability at varying degrees as seen in Table (1); hence they are used in developing the Affordability Index (AI) and the affordability capability audit tool described in Section 5.

In order to include these factors as part of the, AI they are assessed and weighted depending on the impact they have on affordability as shown in Table (1).

The qualitative factors are explained below:

- World Economic Climate (WEC) - The economic climate is influenced by the inflation, interest rate and share prices. Exchange rate fluctuation between two currencies dictates how much one currency is worth in terms of the other. This could have a negative or positive effect on affordability.
- Legislation (L) - Changes in UK, EU and International law, regulations, and protocols concerning environmental, safety, social issues can affect

affordability. These impacts both the WLC at the outset of the project and the affordability of extant projects.

- Quality (Q) - Usually, the customer focuses on a specific project and the financial commitment involved in that project. The customer wants to ascertain that the solution is delivered at high quality. Hence, customer's affordability is influenced by its perception and interpretation of quality within a project.



Figure 5: Qualitative factors affecting Affordability

- Supplier Chain (SC) - Contractors are increasingly dependent on lower tier suppliers to help deliver both products and services for the duration of the availability or capability contract life. It is a major challenge to ensure continuity in the supply chain over the contract life.
- Requirement (R) - The change of requirement increases the WLCC of the project because extra effort is required in redesigning the system especially with be-spoke systems and services.
- Global Competition (GC) - The rules of competition could drive the cost down. If competitors are offering lower prices, the supplier could be forced to reduce the cost of the service.
- Performance-Related Measure (PRM) - In some contracts the customer may not make full payment until the contract has been delivered, hence the level of customer satisfaction with the delivery and performance of capability could impact the customer's willingness to pay based on equipment performance.
- Political Climate (PC) - The aerospace defence industry's operations are typically affected by the nation's political climate. Perceived threats from other nations, could affect the government's willingness to invest in defence projects.
- Unknown (U) - This applies to any other factors which arise depending on the nature of the project.

These qualitative factors would be quantified based on the expert judgment of the project team. Therefore the weighting of qualitative factors will differ for each IPS2 project.

The AI developed by [15], was modified using factors derived from current research shown in Table (1) to reflect the aerospace defence industry. This is presented in equation (1).

An affordability score equal to 1 is just affordable, a score greater than 1 is more affordable while a score less than 1 is less affordable.

Though this AI is derived from the customer's perspective, the solution provider can also use this to understand customer affordability and design capability to accordingly.

- 1 = No data
- 2 = Little amount of data
- 3 = Just enough data
- 4 = Sufficient level of data
- 5 = Plenty of data

Affordability Factors (AF)	Weight (%)
WEC	9
L	11
Q	10
SC	12
R	13
GC	9
PRM	12
PC	13
U	11
Total	100

Table 1 : Weighting scale for qualitative factors

Affordability Index (AI)

$$= \frac{CATS}{WLCC} \left(1 - \left(\sum_{i=1}^n \frac{(C_i - S_i)}{S_i} \right) \frac{1}{n} \right)$$

$$\frac{WEC*9+L*11+Q*10 +SC*12+R*13+GC*9+PRM*12+PC*13+U*11}{100} \quad (1)$$

Where:

CATS = what the Customer has Available To Spend/customer budget

WLCC= Expected Whole Life Cycle Cost for IPS2

C_i = Estimated Cost incurred in the ith year

S_i = Expected spending ability of the customer for the ith year

i = the years where cost exceeds the expected spending ability of the customer in that year.

n = total number of years the cost has exceeded the spending

5. AFFORDABILITY CAPABILITY AUDIT DEVELOPMENT

The affordability capability audit tool is a Microsoft Excel-based tool consisting of 6 worksheets. A number of steps were followed in the development of the tool.

Step 1 – an explanation of aim of the audit tool and the approach taken in designing the tool.

Step 2 - guidance to users on how to provide answers to the questions within the tool.

In order to use the tool, the user would provide a score from 1 to 5 (1 being the lowest and 5 the highest) for each of the questions under each element for all affordability factors.

Step 3 – a presentation of questions to be answered by providing scores between 1 and 5.

This step involves users providing scores for each factor element across the CADMID cycle for all factors in order to predict the capability of the team. There are 3 questions for each of the 3 elements for each of the 6 phases of the CADMID cycle for each of the 11 affordability factors (2 quantitative factors and 9 qualitative factors presented in section 4.2). A screenshot of this is shown in figure (6).

Three elements were chosen which could give an indication as to the level of information and resources the project team possess in order to be able to deliver the capability required by the project. These are Information (I), Tools (T) and Skills (S). For each element three questions were asked as shown in figure (6) in order to realise the capability of the project team to assess affordability based on the availability of tools, information and skills from a past project.

The questions are presented below.

Questions

Information

- (i) Do you have information from similar project?
- (ii) Level of information on current project
- (iii) Ease of interpretation of the information

Tools

- (i) Do you have available tool(s) from past project?
- (ii) Do you have tools for this project?
- (iii) The ease of use of the tool(s)

Skills

- (i) Do you have a team/individual from similar project?
- (ii) Do you have man power currently available?
- (iii) Level of expertise

The first question under each element is an enquiry about the team's ability to apply information, tools or skills from a previous project to the current project. The second question is asking to about the level of information, tools or skills within the current project. The third question is an enquiry about the ease of accessing the information, tools and the level of skills of the workforce in the current project.

Step 4 - Generation and summary of result

The total score for each element is generated under the affordability factors across the phases of the CADMID cycle. This is summarised by averaging the score of all three elements at each phase of the CADMID under each factor to provide a single score for each phase of the CADMID under each affordability factor.

The scores are presented in a colour coded table similar to a traffic light system. (All scores would be rounded to the lowest whole number).

- Sufficient/ plenty of data – any value from 12 to 15. This is represented by a green colour.
- Just enough data - any value from 9 to 11. This is represented by an amber colour.

- No data/ little amount of data – any value from 1 to 8. This is represented by a red colour.

Finally, a single score is presented for each affordability factor at each phase of the CADMID cycle.

The output of the tool provides two main benefits:

- Assess the capability of the bidding team to judge the customer's affordability of a project.

improved AI for predicting affordability at the bidding stage and across the CADMID cycle was initially validated with industrial partners through interview sessions and workshops. Further validation would be done through industrial case studies. The affordability capability audit tool is at its early stage of development; hence it would be refined and further validated with industrial case study.

In conclusion, the following observations were made:

		B	C	D	E	F	G	H	I	J	K	L	M	N	O	P						
1		Answers																				
2		Customer Budget (CB)						Whole life cycle cost (WLC)						Political cl								
3	Questions	C	A	D	M	I	D	C	A	D	M	I	D	C	A	D						
4	Information (I)	I																				
5	(i) Do you have information from similar project	5	5	4	4	4	4	1	4	4	1	5	5	4	3	3	4					
6	(ii) Level of information on current project	5	4	5	5	5	3	3	5	3	3	5	3	3	5	3	3					
7	(iii) Ease of interpretation of the information	1	4	3	5	5	3	5	3	3	5	4	1	5	3	3	3					
8	Total	11	13	12	14	14	7	12	12	7	13	14	8	11	11	10						
9		T																				
10	Tools (T)	C	A	D	M	I	D	C	A	D	M	I	D	C	A	D						
11	(i) Do you have available tool(s) from past project	2	3	5	4	4	2	5	5	3	2	5	2	4	3	2						
12	(ii) Are the tool(s) applicable to this project/ Do you have tools for this project	4	4	3	5	5	3	5	3	5	5	5	3	3	3	3						
13	(iii) The ease of use of the tool(s)	4	2	4	4	4	2	4	5	4	5	4	2	1	2	3						
14	Total	10	9	12	13	13	7	14	13	12	12	14	7	8	8	8						
15		S																				
16	Skills (S)	C	A	D	M	I	D	C	A	D	M	I	D	C	A	D						
17	(i) Do you have a team/individual from similar project	5	3	3	3	4	2	5	5	5	5	5	2	5	5	2						
18	(ii) Do you have man power currently available	5	4	3	5	5	1	3	4	3	5	3	3	3	3	3						
19	(iii) Level of expertise	5	4	4	2	5	4	5	4	4	4	5	3	4	4	4						
20	Total	15	11	10	10	14	7	13	13	12	14	13	8	12	12	9						
21		Individually Total																				
22		Green 4 to 5			12 to 15																	
23		Amber 3			9 to 11																	
24		Red 1 to 2			0 to 8																	
25	The scores are between 5 and 1, 5 being the highest and 1 the lowest score. Also scores 4 and 5 are signified with green colour (there is enough data), score 3 is signified with amber, while 1 and 2 are signified with red (insufficient data). The totals are then represented in the tool below																					
26		Yes/High 4 to 5 No/Low 1 to 3																				
27		AFFORDABILITY TOOL SCORE																				
28		CADMID CYCLE																				
29		C			A			D			M			I								
30		I	T	S	I	T	S	I	T	S	I	T	S	I	T	S						
31		11	10	15	13	9	11	12	12	10	14	13	10	14	13	14						
32		12	14	13	12	13	12	7	12	12	13	12	14	14	14	13						

Figure 6: Capability Prediction Sheet

- Highlight gaps in the availability of information at the bidding stage which is required to measure affordability at different stages of the CADMID.

Information used in the development of this tool was obtained from interview sessions with both customer and solution providers. The tool can be used by both parties to assess capability at bidding stage.

The tool gives an indication of the confidence level about the AI so the customer can take account of risk and uncertainty associated with an IPS2 project.

The tool was initially validated with industrial partners through interview sessions and workshops. The workshops included presentations describing the tool and questionnaire sessions which captured the view of respondents. Most respondents agreed that the tool was useful for affordability assessment at the bidding stage.

6. DISCUSSION AND CONCLUSION

Affordability is a new research area which has not received enough attention from researchers while the PSS/ IPS2 theme has been evolving in recent years. This paper has provided a description of IPS2 with main focus on availability/capability contracts in the aerospace defence industry.

The paper has provided a definition of affordability. Also, it provided a description of the capability audit tool and the AI for affordability.

Though the AI is derived from the customer's perspective, the solution provider can also use this it to understand customer affordability and design capability to accordingly. Most of the work presented in this paper is based on current research being undertaken by the authors. The

- There is a lack of uniform definition of affordability between solution providers and the customer, however, the NoE in AE's definition has been adopted as a standard definition for industry.
- Both solution providers and the customer are not formally predicting affordability of a project over its life cycle; however, an Affordability Index is proposed in this paper.
- The major challenges for affordability prediction has to do with an understanding of customer spend profile. This is because :
 - Availability of data is low
 - There is a lack of understanding about uncertainty
 - There is a lack of understanding of customer value
 - There is a challenge in quantifying the qualitative factors affecting affordability.
 The affordability capability audit tool presented in this paper is designed to fill some of the gaps highlighted above.
- The present paper proposed a methodology to predict affordability of a project at the bidding stage using qualitative and quantitative factors for the defence aerospace industry.
- Based on the literature and interaction with industry, the major qualitative factors (top 4 based on the weighting in Table (1)) affecting affordability: political climate, requirement, supply chain, performance related measure and the major quantitative factors: WLCC and Customer budget were identified.

The limitations of the paper are outlined below:

The first limitation of the research is that it is specific to the aerospace defence sector. Nevertheless, it is possible to adapt ideas from this research in developing AI for other sectors. The questions included in the tool would be refined to provide more detail in order to improve the robustness of the tool.

Also the metric developed in this research would be refined as it reaches the later stages of validation.

Further research direction includes the understanding of:

- The link between customer value and affordability. This would help to understand how a change in customer value would affect affordability.
- Use of AI to inform project management and derive metrics for project control. This would be useful in helping to derive performance measurement metrics to monitor and control the performance of a project at different stages of the CADMID cycle.
- Affordability research that can inform budget setting. The customer budget is a major factor affecting affordability so the research could help to inform the budget setting process so the budget is robust enough to help improve affordability.

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