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An automated optimisation framework for the development of re-configurable business processes: a web services approach

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The practice of optimising business processes has, until recently, been undertaken mainly as a manual task. This article provides insights into an automated business process optimisation framework by using web services for the development of re-configurable business processes. The research presented here extends the optimisation framework by introducing additional web services as a mechanism for facilitating process interactions, identifying enhancements to support business processes and undertaking three case studies to evaluate the proposed enhancements. The featured case studies demonstrate that an increase in the amount of available web services gives rise to improvements in the business processes generated. This research highlights an increase in the efficiency of the algorithm and the quality of the business process designs that result from the enhancements. Future research directions are proposed for the further improvement of the framework.

Keywords: web service; business process; optimisation

1. Introduction

Business processes map complex organisational interactions, often describing tasks that are undertaken manually. However, business process automation can be achieved by translating manual procedures or using semi-automated tools. Johansson et al. (1993) define a business process as ‘a set of linked activities that take an input and transform it to create an output’. Ideally, the transformation that occurs in the process should add value to the input and create an output that is more useful and effective to the recipient either upstream or downstream. ‘The aim of a business process is to perform a business operation, i.e. any service-based operation that is producing value for the organisation’ (Tiwari, Vergidis, and Turner 2010). According to Vergidis, Tiwari, and Majeed (2008), business process definitions are usually very simplistic or specific to the industry from which they emerge.

It may be asked why there is a need to optimise a business process? Hammer (1990) indicates that companies tend to use information technology to speed up old business processes without changing them. This can lead to inefficient processes that do not recognise or incorporate more recent automated process steps. Optimisation, in relation to business processes, is about improving performance and achieving maximum results within time, cost and efficiency parameters. Vergidis et al. (2007) suggested that improving performance helps to establish competitive advantage for organisations. These authors also noted that optimisation has a direct impact on costs and process duration.

Business processes are represented in this article as being composed of tasks, the discrete steps or subcomponents of a process, and resources, the inputs and outputs of a task. Within this article each task will be represented by a web service performing a specific function. Resources within a process link up all of the tasks, they are the inputs and outputs of each web service in a process (in graph theory resources, as described in this article, can be thought of as edges). The use of web services in this research stems from the rise of the service-oriented architecture (SOA), on which web services are based. The functionality of each web service is described by the interface it exposes. The interface of a web service defines the inputs it may receive and the outputs it returns. Nagappan, Skoczylas, and Sriganesh (2002) state that web services are modular business applications that expose business logic as a service over the Internet by subscribing, invoking and finding other services. The concept of interchange-ability of web services is an important process improvement benefit utilised by the business process optimisation framework (bpo^F) to allow for tasks to be swapped in and out.

Each task within a process can be given attributes such as cost and efficiency. In this way the task of a process may be changed in order to change the overall attribute totals, such as reduce the overall cost of a process if each task has a cost attribute attached to it. In the case studies within this article, the attributes cost and efficiency are used as optimisation parameters (reduced cost and increased efficiency are the target outcomes).

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The bpo^F presented in this article is a soft computing approach utilising evolutionary multiobjective optimisation algorithms (EMOAs). Evolutionary techniques allow for the production and exploration of a population of diverse process designs based on a specific set of process requirements (Tiwari, Vergidis, and Turner 2010). Wang, Salhi, and Fraga (2004) note that process optimisation is a difficult task due to the inherent discontinuous nature of the underlying mathematical models.

In terms of related work, Hofacker and Vetschera (2001) have attempted to transform and optimise a business process model using GAs though they concede that the results they obtained were not satisfactory. Tiwari, Vergidis, and Majeed (2006) and Vergidis, Tiwari, and Majeed (2006) extended the mathematical model of Hofacker and Vetschera (2001) and utilised multiobjective optimisation algorithms, such as the Non-Dominated Sorting Genetic Algorithm 2 (NSGA2). The results obtained from these investigations were satisfactory and led to the development of the bpo^F by Vergidis (2008). The aim of the research presented in this article is to show that an increase in the amount of available web services gives rise to improvements in the business processes generated. In the case studies, the use of a modified and extended web service library is evaluated to this end.

2. Business processes in manufacturing

Increasingly manufacturing is looking to the operation of their business processes for efficiency gains. This is particularly true in the case of business processes relating to the supply chain (Huang, Sheoran, and Keskar 2005). Makris and Chryssolouris (2010) have looked at the modelling of the supply chain for highly customised products and have demonstrated the complexities involved in the production and delivery of such products in real time. Real-time manufacture for mass customisation requires a highly flexible and adaptable supply chain (Mourtzis et al. 2008; Makris, Zoupas, and Chryssolouris 2011); such a supply chain must also interact with business processes in real time, which suggests that business processes must also be adaptable to real-time changes in the supply chain. In addition, manufacturers are looking to offer services in combination with their products, and in some cases selling the 'use' of their products rather than the products themselves (this concept of the Product Service System is explored further in Baines et al. 2007). In all cases, additional emphasis is now placed on the efficient management and operation of business processes within manufacturing organisations.

Many works exist in the area of automated process planning and scheduling for manufacturing, some using soft computing techniques such as simulated annealing to achieve the optimisation of planning and scheduling of processes (Li and McMahon 2007) [a review of the latest trends in automated process planning may be found in Xu, Wang, and Newman (2011) and in Phanden, Jain, and Verma (2011)]. However, the research outlined in this article differs from these works by focusing on the use of web services as components of an optimised business process. To the knowledge of the authors of this article, the work of Vergidis (2008) and the further exploration detailed in this article are the only recent works to advance the area of business process optimisation based on the use of web services.

2.1. *Web services and business processes*

Today organisations closely cooperate with partners across the globe. However, the business processes of one organisation are often not compatible with those of other partner companies. In order to address this, Chryssolouris (2004a, 2004b; and later in Makris et al. 2008) have looked at ways of modelling cooperating information systems to allow for Internet-based supply chains to become a reality. Web services are increasingly a subject of attention in the business process arena. The idea of seamless information exchange between different systems promotes new ways of compiling business processes using various web services. Web services are platform independent and are based on the SOA. According to Nagappan, Skoczylas, and Sriganesh (2002), SOA is the latest development in distributed computing. SOA enables application functions, objects and processes from different systems to be exposed as services. Hurwitz et al. (2007) stated that SOA is the architecture for building business applications. It is in this context that a process could be constituted of web services within SOA architecture (Cheng and Lai 2011).

Commentators such as Papazoglou (2003) do provide criticism of web services, indicating that there are limitations in business semantics, and a wide proliferation of emerging technologies. Web services, at present, are often poorly described and difficult to locate. To this end Kaye (2003) criticises web services for being ambiguous in terms of their meaning because they do not address semantics. Clabby (2003) emphases the importance of a formal unified public UDDI registry that can facilitate global storage for web services. Research in this area is advancing. A consortium of four different organisations aims to develop a web service discovery platform that inherits the best qualities of Web 2.0 (Service-Finder 2010). Their main focus is to provide a single repository for web service descriptions. For the interfacing of business processes with web services, the XML standard can be a useful medium for data exchange. The work of Choi et al. (2003) presents an XML language for the definition of business processes. Indeed, there are a number of XML-based languages that may be used to describe business processes, such as BPML (Aissi, Malu, and

Srinivasan 2002), BPEL and XPDL (Shapiro 2002). Shapiro (2002) provides a good overview and comparison of such languages. Workflow management systems and their interactions with/porting though web services have been explored by Alexopoulos et al. (2011). In this work, Alexopoulos et al. (2011) examine the area of collaborative computer-aided production engineering supported by a web service-enabled workflow system. The web service-enabled workflow for a supply chain is the subject of research by Makris and Chryssolouris (2013). In this work, the authors propose a decision-support software system for the modelling of a supply chain of an automotive company; this system utilises web services for the purpose of communicating with supply chain partners and obtaining information on parts availability (Makris and Chryssolouris 2013).

With many avenues now being pursued in the harnessing of web services for increased business process interaction, one point of consensus can be drawn from the current state of research; there is only limited work on how web services contribute towards the business process optimisation discipline.

3. Business process optimisation framework (bpo^F)

Vergidis (2008) proposed an evolutionary multi-objective optimisation framework for business process designs, the bpo^F. The central concept behind bpo^F is to enable the automated generation of alternative business process designs using EMOA techniques [a commentary on EMOAs and their use is given by Coello Coello (2005)] given an original process design and a set of constraints on that design. Through the production of alternative designs the aim is to generate and identify individuals with high fitness levels, with the aim of eventually producing an optimised process design after a number of generations (Vergidis 2008).

3.1. Main steps of the business process optimisation framework (bpo^F)

The main steps and the structure of the bpo^F are shown in Figure 1. This research utilises the EMOA NSGA2 (Non-dominated Sorting Genetic Algorithm 2) and the Large-Scale Search Algorithm (LSSA) (the LSSA is used to generate the search space). NSGA2 is responsible for plotting the optimised results. It is the most popular engine for use in the optimisation of fragmented data. The main parameters for use with bpo^F are shown in Table 1.

Table 1. General parameters.

Population	Generations	Crossover probability	Mutation probability	Objectives
250	25,000	0.8	0.2	2

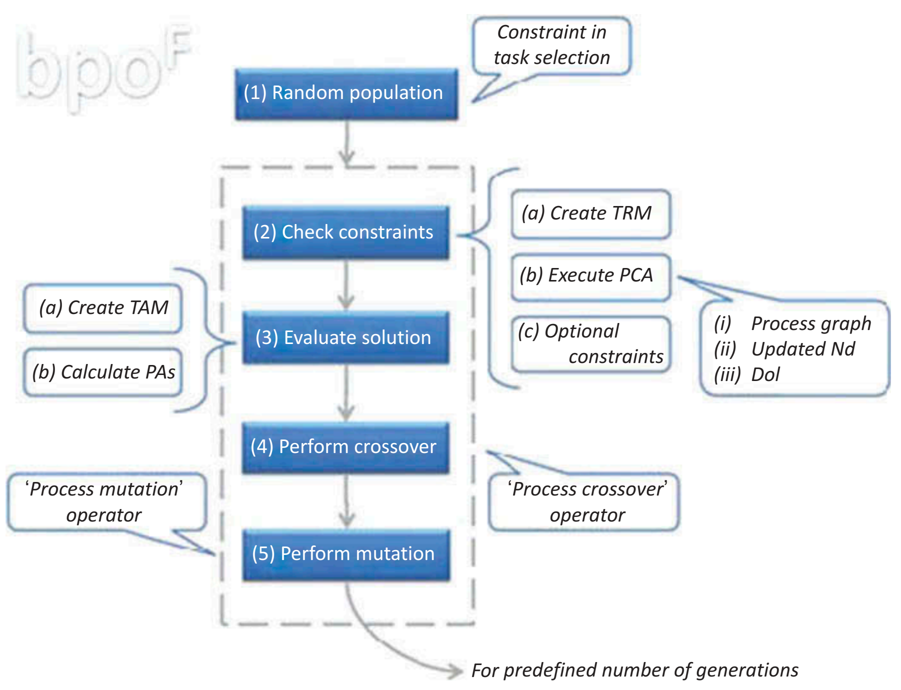

Figure 1. The main steps of the bpo^F (Vergidis 2008).

From Table 1 it can be seen that the population is set to 250. This means that 250 versions of a business process are produced for each generation that the evolutionary algorithm is run for (25,000 generations are iterated, shown in Table 1). Table 1 also demonstrates that two objectives are being optimised; that is, cost, represented in the case studies as service delivery price (SDP), and efficiency, represented as service fulfilment target (SFT). The bpo^F, presented here, is described in detail in Vergidis (2008).

The bpo^F consists of five steps:

(1) *Generate random population:* The first step of the optimisation process is the generation of a random population. This step occurs only once in the optimisation process as then the population is evolved for a defined number of generations. However, for each of the sets there is a constraint in the random allocation of tasks. The constraint is that a task must appear only once in the same set. This constraint avoids having duplicate tasks in one set and in a potential business process design. Such duplicate (repeated) tasks are difficult to identify and only a few automated techniques in the business process field address this problem space (Turner et al. 2012). Solving this problem is complex as it is necessary to identify the execution context of each occurrence of a duplicate task in order to determine a differentiation (Goedertier et al. 2009). Solving the issue of duplicate tasks would require the use of an additional technique, such as the use of a classification learner as proposed by Goedertier et al. (2009) (these authors also provide an additional commentary on duplicate tasks).

(2) *Check constraints:* For each solution of the population, the problem constraints are checked. Note that bpo^F checks the constraints prior to solution evaluation for a specific reason: *the constraints modify the solution.* One particular constraint measures the degree of infeasibility (DoI) of the solution. It is here that the process composition algorithm (PCA) is run. The PCA is an algorithm for composing new business process designs. The PCA ensures that there is a one-to-one relationship between the inputs and outputs of tasks within the solution to ensure consistency in the optimisation. If a solution cannot be built into a graph (e.g. because edges between graph tasks are missing), the solution is deemed infeasible and a penalty is added. Additional optional constraints can force solutions to contain or exclude a certain set of tasks.

(3) *Evaluate solution:* The solution evaluation involves two stages based on the proposed representation: (a) The task attribute matrix (TAM) is created and (b) the various process attributes (PAs) are calculated. The TAM is created based on an updated version of the solution involving the tasks in the design and their attribute values. Based on this matrix, the solution is evaluated in terms of the process attribute values.

(4) *Perform crossover: Crossover* is a genetic operator that exchanges information between two solutions. Crossover occurs directly in the N_d set of each solution. Initially, the solutions are selected for crossover based on a given crossover probability. The solutions that are chosen for crossover are split into pairs. For each pair, a unique crossover-point is defined based on a random number (between 1 and N_d-1). Note that step 2 checks whether the solution is feasible.

(5) *Perform mutation:* This genetic operator randomly alters information in a chosen solution. The operator is applied on the N_d set of tasks of a particular solution. When mutation occurs, a task is replaced with an *arbitrary* task from the task library (the task library is a set of tasks which may be inserted into a given process if the input and output resources of a task, selected from the library, correspond with the input and output resources of a set of adjoining tasks in that process).

In this approach, the LSSA maps all possible solutions that constitute the overall search space. NSGA2 complements LSSA by providing the capability to visualise the results in the form of a scatter graph with Pareto front. In order to view individual results and process graphs, the JGraph (2011) software is used. JGraph (2011) translates each individual into a flowchart showing tasks linked by resources (and includes AND and OR construct indicators).

3.2. Business process optimisation using web services

As mentioned earlier, each task in the process is represented by a web service. Online directories of web services have been consulted in order to identify and select relevant services [directories such as Web Service List (2013), Service Repository (2013) and Programmable Web (2013), among others]. It is worth noting that this research does not consider the implementation of specific web services, just their inputs and outputs. As such the requirements for participating web services have been encapsulated into a number of attributes. Each web service has been rated with the addition of two attributes: cost (SDP) and efficiency (SFT). The SDP defines the cost to the customer of their use of that particular service (Vergidis 2008). The SFT represents the service provider's ability to

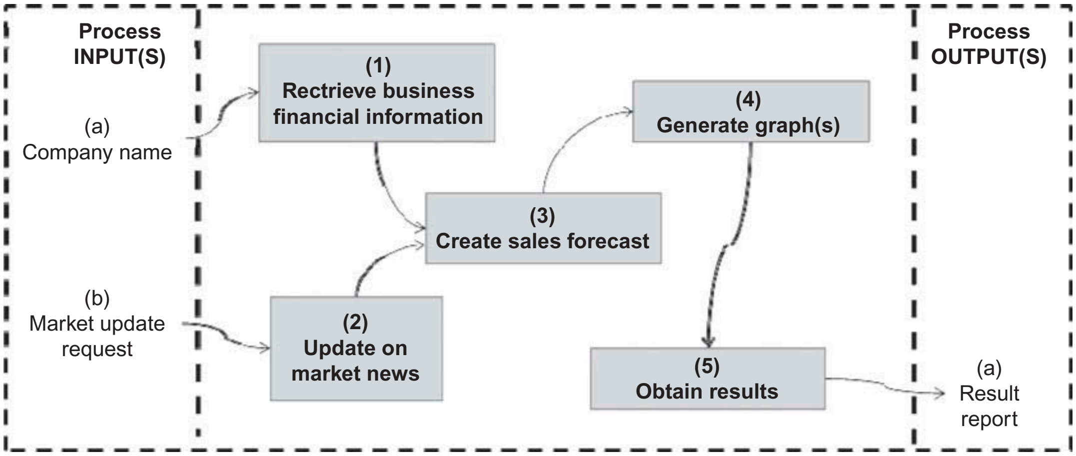

Figure 2. Initial business process design of the sales forecasting scenario (scenario 1).

deliver a set of predefined benefits to a customer within a set service time window (Vergidis 2008). The attributes SDP and SFT, when used in combination, describe the value of the service to a customer and allow for competing services to be compared with each other. Although the SDP and SFT values assigned to web services in this work are fictional, they do represent a potential rating mechanism for web services. Each business process can be composed of many web services generated in a random order. Every web service has its specific function which depends on its inputs and outputs. This ensures that the algorithm is able to pick up a better web service, depending on the requirements. For each scenario, appropriate web services are chosen and are converted into a script readable format for the algorithms. After execution, NSGA2 generates 250 graphical business processes and a log file with cost and efficiency values. These values are plotted with a scatter diagram to compare the results.

Three scenarios are featured in this article. The first scenario describes an automated sales forecasting process (scenario provided by Grigori et al. 2004). The scenario is described by the initial business process design shown in Figure 2. The initial process design shows the main process steps (each represented by a web service) and the inter connections between the steps. The scenario starts with two inputs: (a) company name and (b) market update request.

One output is produced in this scenario: results report (which is the completed sales forecast). An information retrieval stage, whereby financial information about a business is retrieved along with an update from the financial markets, is the first step in this scenario. In subsequent stages, a sales forecast is created and a graph service provides a number of visualisations of the forecast data for inclusion in the report.

Scenario 2, shown in Figure 3, describes the placing of an order in an online store [scenario provided by Havey

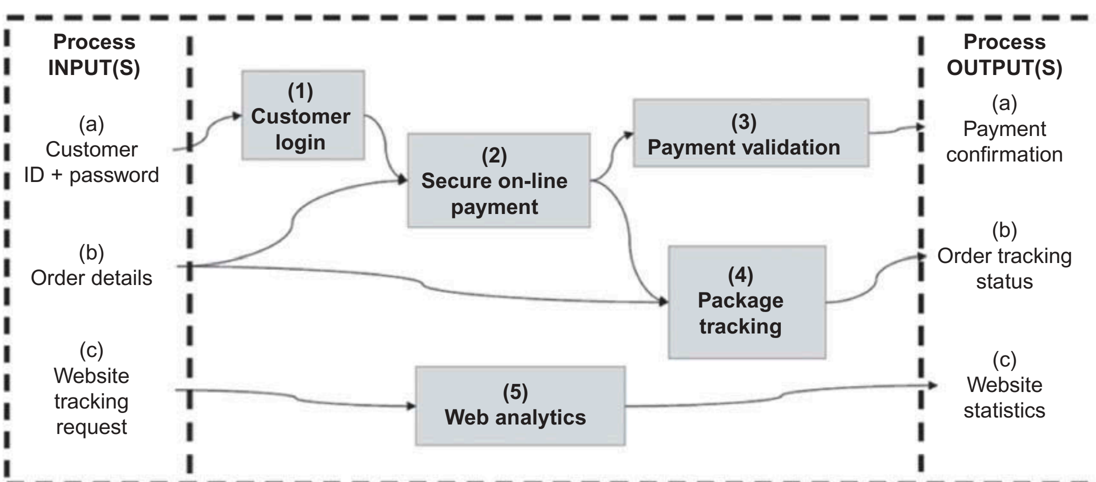

Figure 3. Initial business process design of the online order placement scenario (scenario 2).

(2005)]. This scenario demonstrates a process that would play a key role in the purchasing supply chain for a manufacturer, if the supply chain were composed of web service-enabled links between the partners. The initial process design for this scenario starts with three inputs: (a) customer ID & password, (b) order details and (c) website tracking request (required to track the customer's progress through the website). The customer credentials are necessary to access the online store and form the first step of this process. A secure online payment is then made for the goods, shown in step 2 (Vergidis 2008). Paying for the order invokes the payment validation in step 3 and the monitoring of the order progress, step 4. The web analytics track the customer's progress in the website and is the final step. Three outputs are evident from this process: (a) payment confirmation, confirms that the payment processing is successful; (b) order tracking status returns the order status in terms of delivery to the customer and (c) website statistics record the customer's behaviour in the website and influence the store's marketing strategy in terms of a customer's individual needs (Vergidis 2008). In the case of the manufacturing supply chain, the task online payment may well be composed of electronic order forms, and invoicing subtasks and the data analytics task may well compile statistics on order fulfilment and delivery times.

Scenario 3, shown in Figure 4, describes an initial design for a fraud investigation process [scenario provided by Havey (2005)]. The process requires one input, the security credentials of the customer. The first step of the process utilises the security credentials to allow the customer access to the data. Steps 2 and 3 are executed in parallel; one check is carried out on the customer's identity and one on their credit history. After the checks in steps 2 and 3 are completed, the outcomes are compiled into a report which forms the single output of the scenario.

Table 2. Example partial task library (used in scenario 2).

No.	Task name	Input (s)	Output (s)	SDP	SFT
0	Achworks soap (Rico Pamplona)	1,2	3	208	113
1	Drupal authentication	0	1	200	103
2	Entrust login	0	1	206	103
3	EcommStats web analytics	6	7	218	112
4	Internet payment systems	1,2	3	226	105

Table 2 shows an example task library for use with bpo^F. In Table 2, it can be seen that each task is represented by a web service, with each web service requiring a number of inputs and outputs. The cost (SDP) and efficiency (SFT) attribute values for each web service are also shown. In order to expand and refine the web service library beyond the work of Vergidis (2008), it has been necessary to employ a categorisation of web services.

Only limited research exists on the classification web services. As a result, the optimisation algorithm needs to spend additional resources to find a service. Building a web service library is important for categorisation purposes and for the provision of data to the algorithm for the execution of experiments. The most common approach to web service categorisation is to classify web services by their functionality. The intention is to help bpo^F to find appropriate web services more quickly. This categorisation strategy comprises three different initiatives. Large Internet companies such as Google, Yahoo, eBay and Amazon expose a number of different web services through their APIs. They also attempt to provide a directory with basic categories that can be assessed in terms of the functional characteristics of web services. Another approach is to study the library in terms of the inputs and outputs for each web service and make a comparison

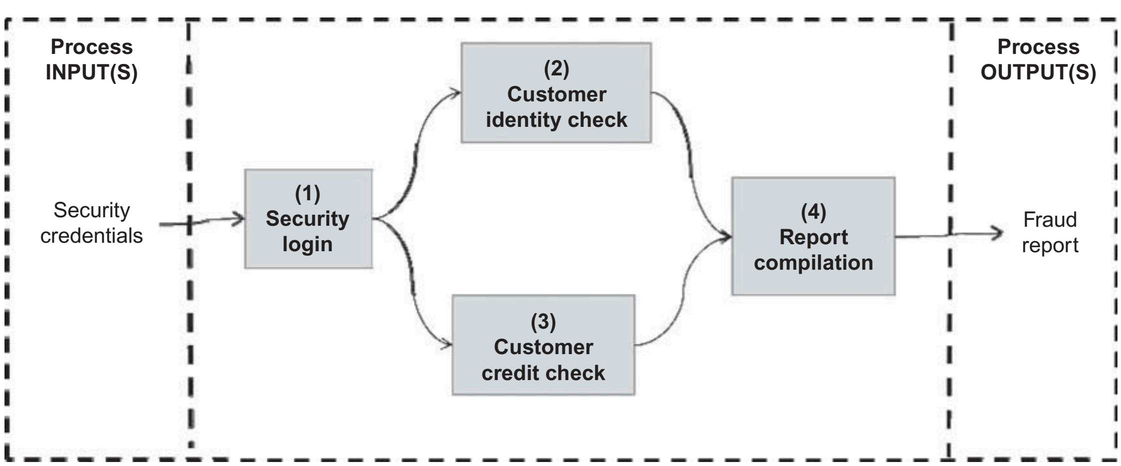

Figure 4. Initial business process design of the fraud investigation scenario (scenario 3).

Table 3. Web service categorisation for use with bpo^F.

Functionality	Description	No. of web services
Information analysis	Responsible for searching, evaluating, comparing, forecasting, listing and monitoring information	21
Event-driven services	Responsible for providing notifications and alerts based on triggers	10
Security checks	Perform verification checks to detect frauds, assess risks and validate information	8
Location-based services	Provide geography-related services	8
User profile	Involve operations with user accounts	8
Statistic services	Track real time and historical records to generate reports	7
Payment processing	Facilitate purchasing process from filling shopping basket to confirming payment	6
Records management	Update, delete, remove, add, amend and edit	6
Data manipulation	In charge of exchanging information between different parties, converting and calculating new combinations and providing translating or transliterating services	6
Authentication services	In charge of identifying requester's credentials and authorising requester to access or to do certain actions	5
Integration services	Providing services for embedding information by integrating third party services and their results into own web services and business processes	5
Transaction	Services that support transactional processing	4
Online order placement	Placing and managing online orders	2
Communication	Provide messaging, networking, hosting or queuing services	1
Problem solving	Involve services that bring two parties to do the job each other	1

on that basis. Lastly, there is an opportunity to assess web services by business models. Almost every web service is built on a revenue raising basis. Javalgi et al. (2005) stated four main Internet activities which add value to information-based products: search, transaction, evaluation and problem solving. The three initiatives described earlier have influenced the route selected for the categorisation used in this work. After creating an enlarged web services library in the previous section, analysis was completed to detect the most frequent transformational activities and unite them by functional groups. The categorisation is displayed in Table 3.

For each of the libraries, used in the three scenarios employed in the work of Vergidis (2008), the categorisation in Table 3 was used so that suitable additional web services could be manually added to each library. As mentioned before, the scenarios featured in this article are the same as outlined in the work of Vergidis (2008). Only the task libraries have been expanded over those used in the work of Vergidis (2008) [i.e. they include the tasks provided in Vergidis (2008) plus additional tasks]. In terms of the number of services added over the set used in Vergidis (2008), on average between two and four additional web service tasks (with similar competing functionality) have been added to the library. For scenario 1, the web service library used by Vergidis has been enlarged by the addition of 21 new tasks; for scenario 2, 19 tasks were added to those used by Vergidis (2008); and for scenario 3, 41 additional tasks were added. The web service categorisation allowed for the grouping of common web services aiding the enlargement of the web service libraries used in Vergidis (2008).

4. Optimisation results

4.1. Business process design analysis

The aim of business process optimisation is the automated improvement of business processes using prespecified measures of performance. The importance of business process optimisation lies in its ability to re-design a business process based on quantitative evaluation criteria. This concept

Table 4. Scenario A.

Case	Tasks	Differences	Service delivery price	Service fulfilment target
A1	4	No payment service	843	449
A2	5	Payment service added	1044	559
A3	6	User authentication, prediction and address verification services added	1219	648
A4	7	Three ways of providing authentication services	1422	753
A5	8	Google elevation service added	1631	867

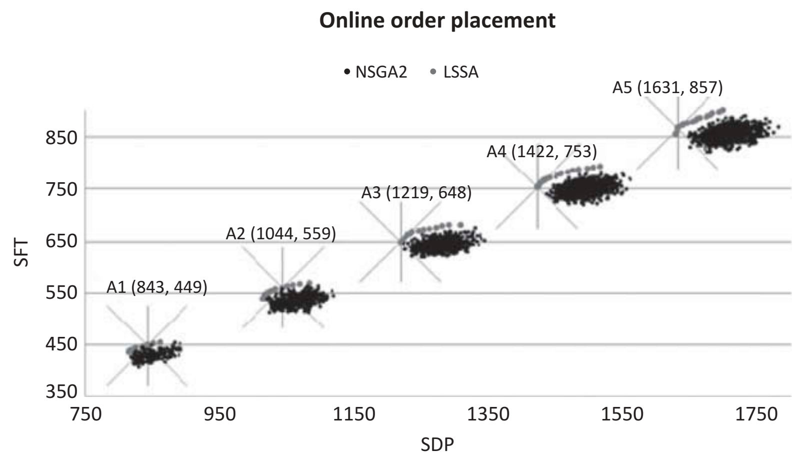

Figure 5. Scenario A: NSGA2 and LSSA.

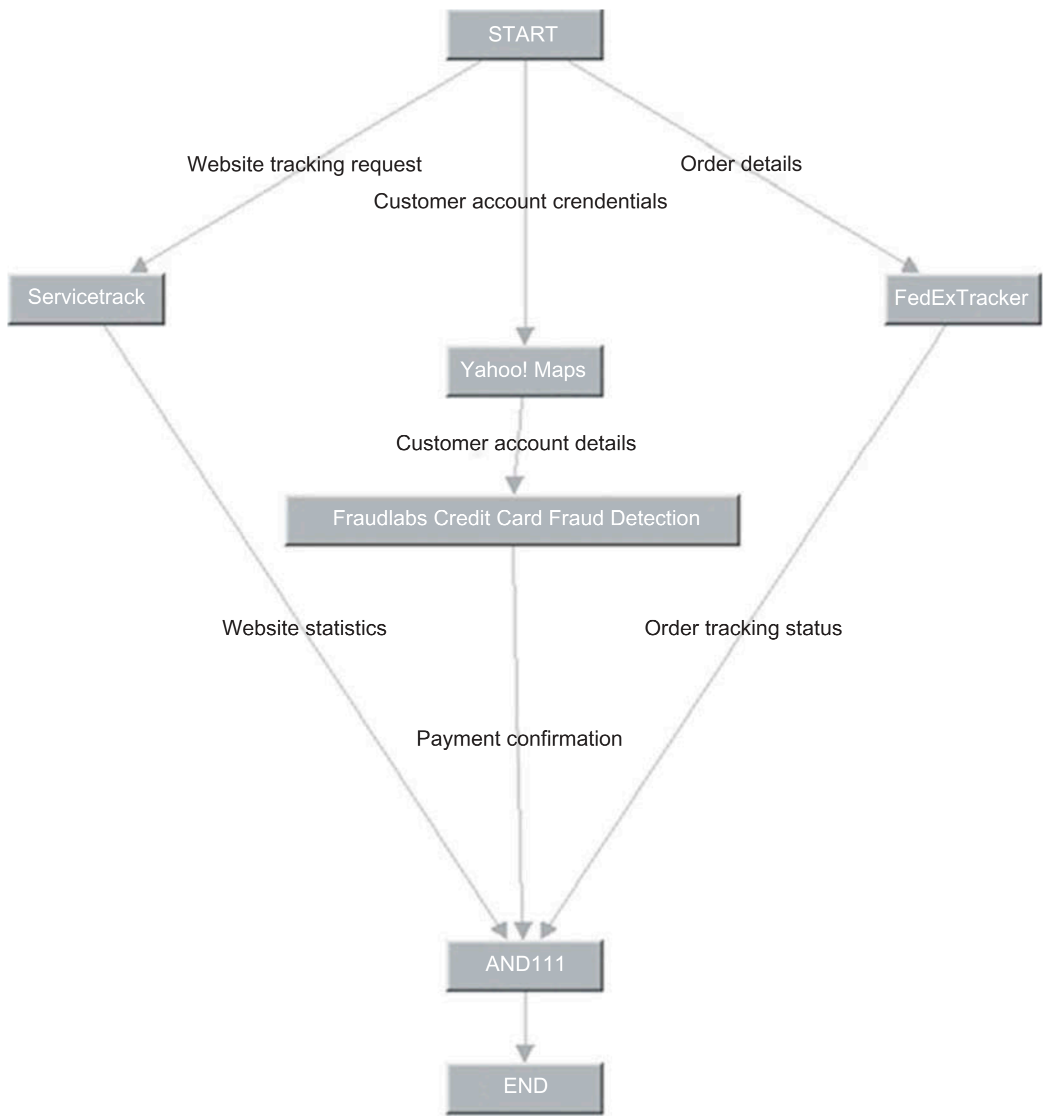

Figure 6. Scenario A: A1.

stresses the need to generate alternative business process designs based on the given process requirements and quantitatively evaluate and compare these designs. In this research, two parameters are being optimised: the cost (SDP) and efficiency (SFT) values for each web service help in the evaluation and selection of 'optimal' process designs. In order to observe and analyse differences between business process designs, with each process design containing a different number of tasks, it was first necessary to generate five cases of a single scenario A as detailed in Table 4. The resulting process designs are shown in Figure 5 represented by point clouds within a scatter graph (each point in the cloud representing a solution). The optimised results are generated by the NSGA2 algorithm (shown as light grey dots), and the search space for all solutions is sketched by the LSSA algorithm (shown as dark grey dots) for each of the scenarios.

4.2. *Scenario A: online order placement*

The algorithm generated five clouds with optimised results (light grey dots) and the overall search space (dark grey dots) (see Figure 5), with each cloud containing solutions with a set number of tasks. From each sample, one business process design, generated by NSGA2, was chosen. Table 4 clearly demonstrates the differences between the five test cases.

A number of observations can be made about each of the selected test case results:

- A1 contains a limited number of tasks (see Figure 6). It is able to fulfil the order only partially as there is no payment service selected. It has low cost and efficiency accordingly. As a result, some basic functions are missing.
- A2 and A3 provide comprehensive process designs that are able to deal with customer orders and track information about the order (see Figures 7 and 8).
- A4 enhances the business process design with alternative ways of achieving authentication (see Figure 9). This can be treated as an attempt to provide a higher quality service.
- A5 is most complex containing basic functions with additional web services (see Figure 10). The cost and the price clearly illustrate its benefits. Alternative web services are able to provide the same function. This means that better services in terms of cost and efficiency can be chosen if required.

4.2.1. *Results of experimentation*

This section presents the results gained from the optimisation of the three process scenarios set 1out in Section 3, using bpo^F as the optimisation engine. In order to determine the effect of extending the web service library, the results of Vergidis (2008) gained for the same three scenarios are presented along with the authors' results. The results are displayed in the form of scatter graphs. As mentioned earlier, in this research two parameters are being optimised: the cost (SDP) and efficiency (SFT) values for each web service help in the evaluation and selection of 'optimal'

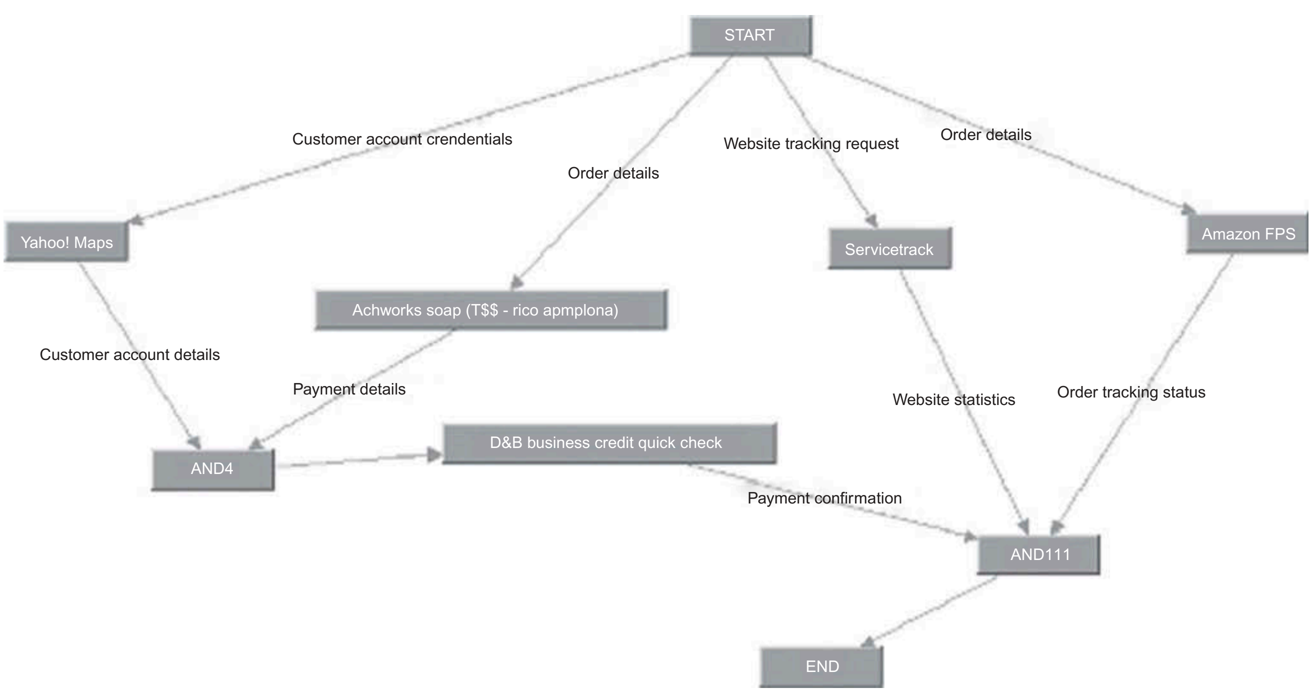

Figure 7. Scenario A: A2.

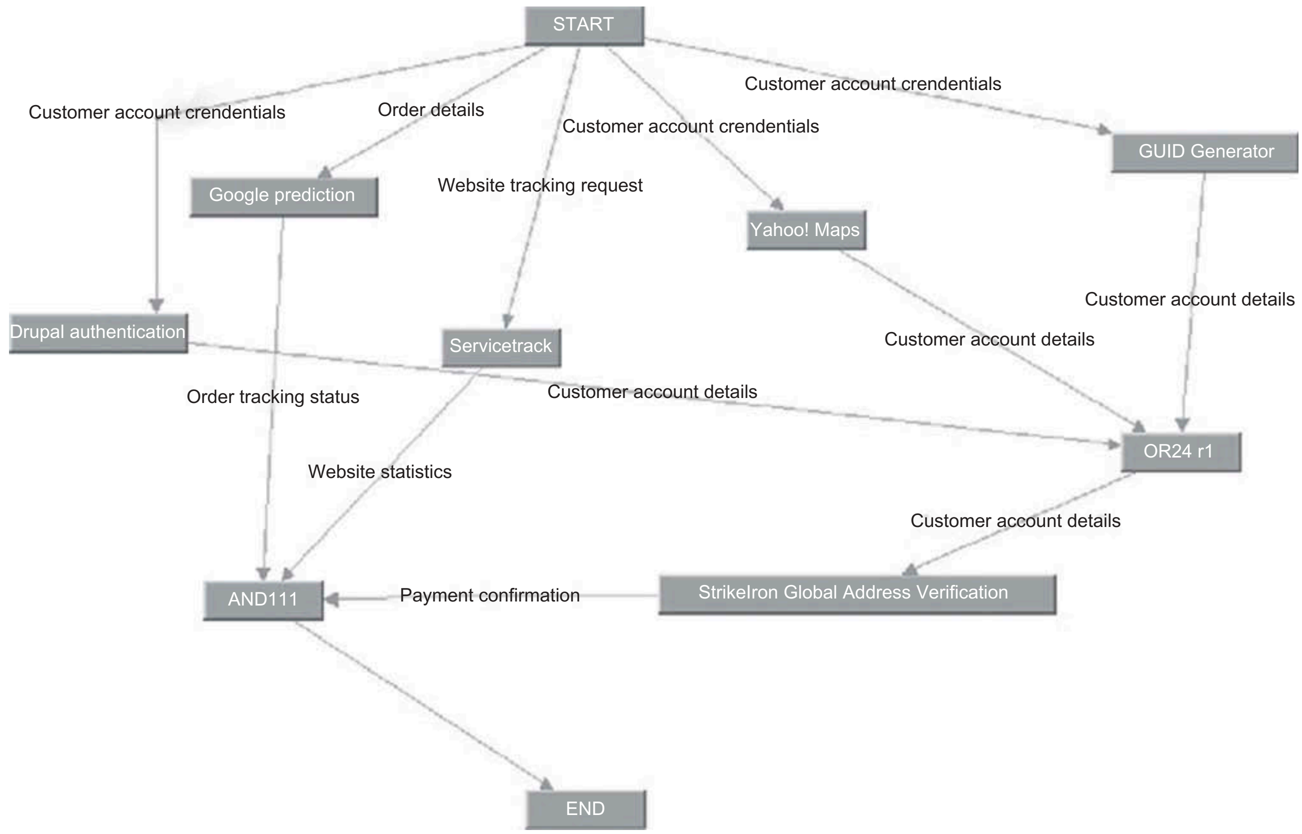

Figure 8. Scenario A: A3.

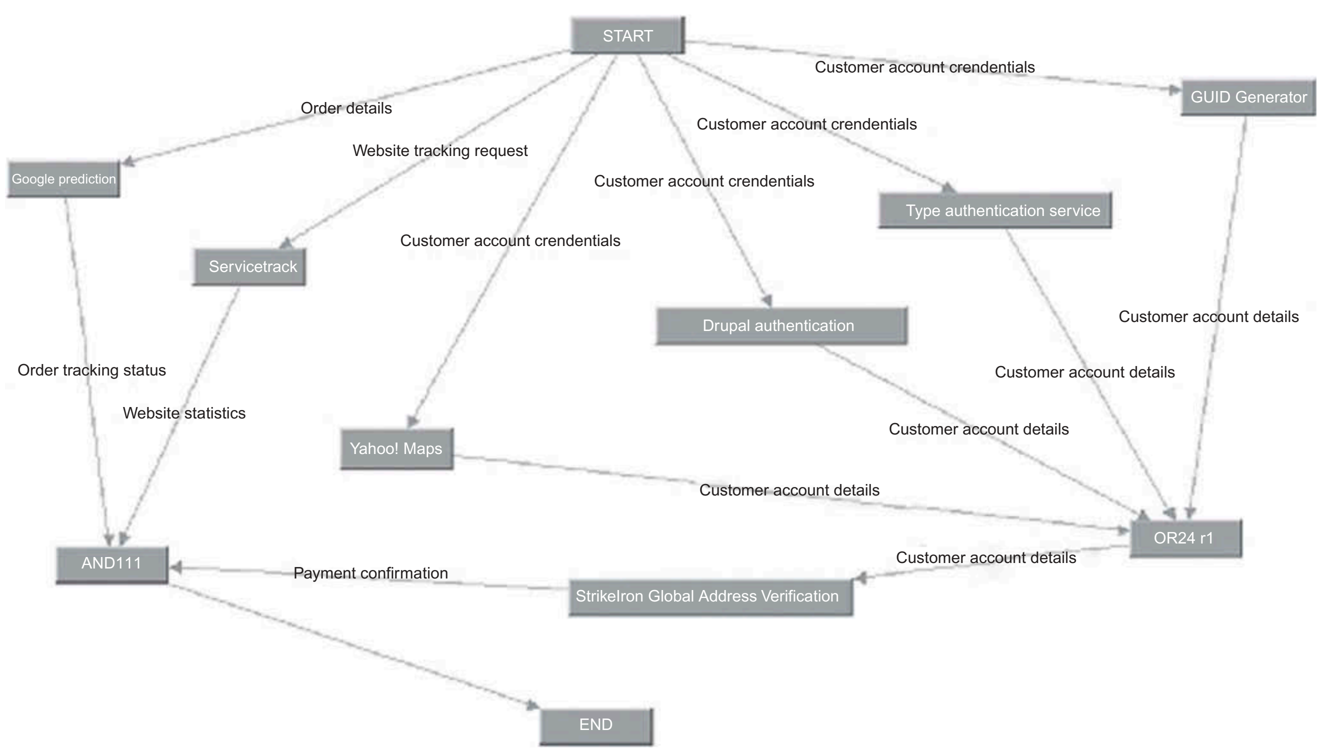

Figure 9. Scenario A: A4.

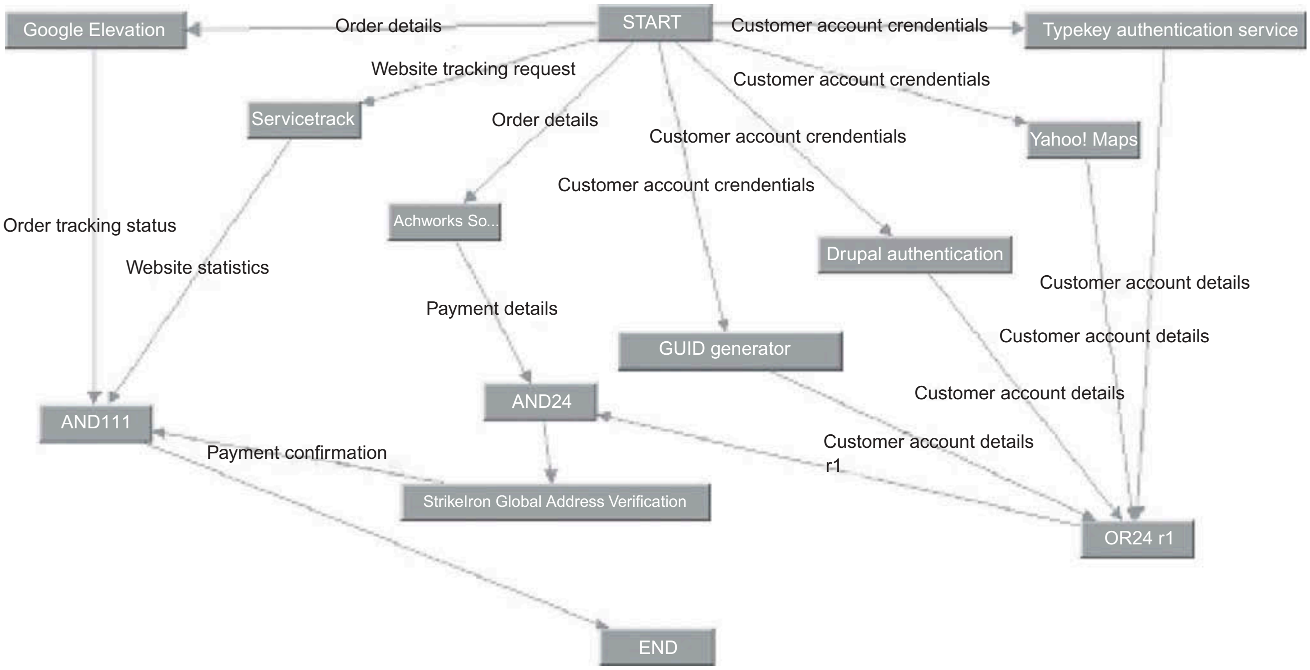

Figure 10. Scenario A: A5.

process designs. The overall search space is estimated to be composed of at least 1000 unique individual solutions for each scenario. It is thought that the effect of introducing an expanded task library has the effect of increasing the size of the search space even further (Vergidis 2008). No exact search space figures have been provided in this research due to the computational expense in obtaining such results.

4.3. *Scenario 1: demonstrating bpo^F*

This scenario modelled a sales forecasting process. The results are shown in Figure 11. In Figure 11, the overall search space is represented by the darker dots with the optimised results shown in light grey. Each cloud represents a set of process results of a given size (e.g. in the cloud containing point B1 for each process has four tasks). Three test cases are highlighted in Figure 11. The differences between the cases are shown in Table 5.

Table 5. Test case differences for scenario 1.

Category	Case	Tasks	Differences	SDP	SFT
Statistics, information analysis, event-driven services	B1	4	No chart service	853	446
	B2	5	Chart service added	1056	553
	B3	6	More services added with charting capabilities	1257	658

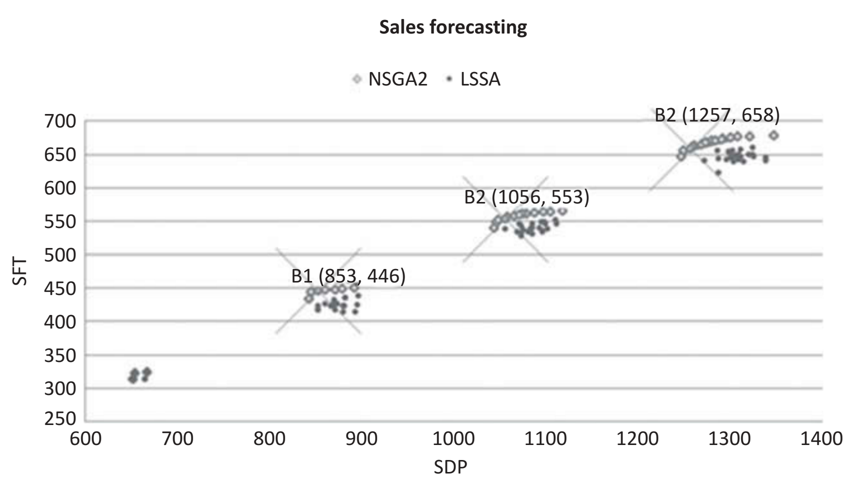

Figure 11. Scenario 1 results.

4.3.1. Scenario 1: a comparison between published and authors' results

As mentioned before in order to effectively assess the use of an enlarged task library, it is necessary to compare the authors' results with the published results of Vergidis (2008). Such a comparison should highlight differences in the way NSGA2 generates output in terms of efficiency and cost. The NSGA2 algorithm in bpo^F has, in both cases, been used to obtain the results displayed in this section. Using the same scenarios as Vergidis (2008), though with an enlarged task library, the following results were obtained as shown in Table 6 and in the form of the process graphs in Figure 12 [Vergidis (2008) result] and Figure 13 (authors' result). With this scenario the differences between the authors' results and those obtained by Vergidis (2008) are minor. Though by looking at Figure 14 it can be seen that curve of values from the authors' results (shown as black dots) is slightly better than that achieved in Vergidis (2008) (grey dots).

Table 6. Result comparison for scenario 1.

Criteria	Vergidis (2008)	Authors' results
Tasks	6	6
Cost	1264	1261
Efficiency	663	663
ANDs	2	2
ORs	2	2
Unique services	Xignite Get Balance Sheet	Mergent Company Fund
Web services	20	41

Both results have an equal number of tasks and clauses. The use of the NSGA by Vergidis (2008) produced more expensive results than that achieved by the authors.

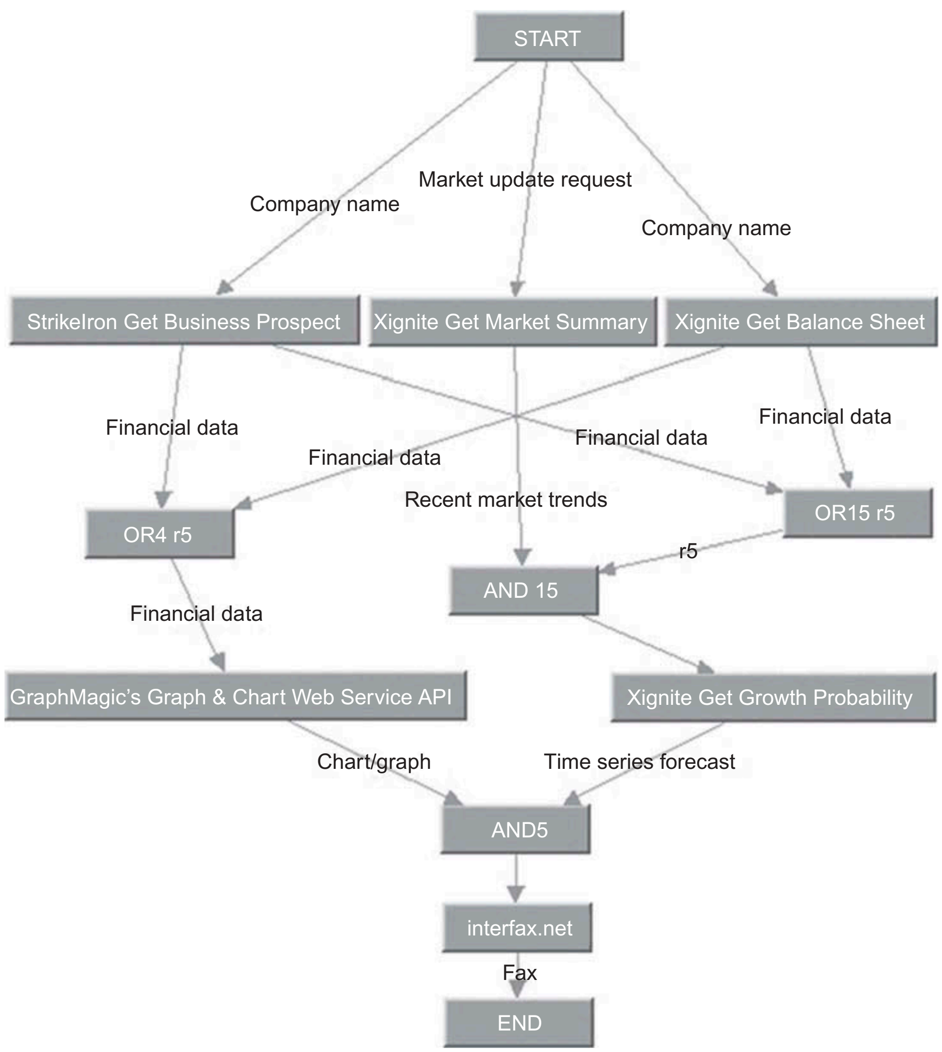

Figure 12. Scenario 1 (Vergidis 2008).

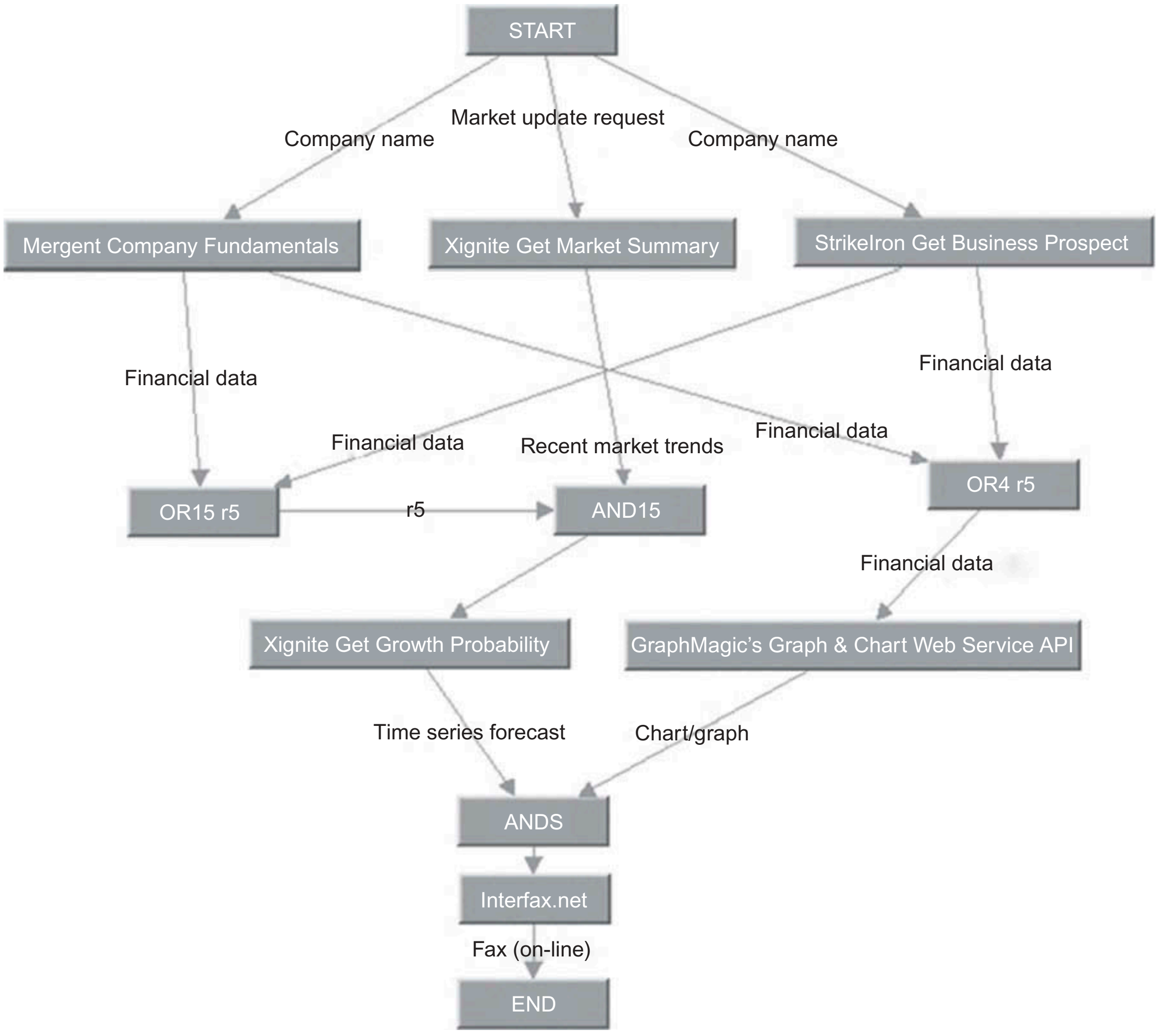

Figure 13. Scenario 1: authors' results.

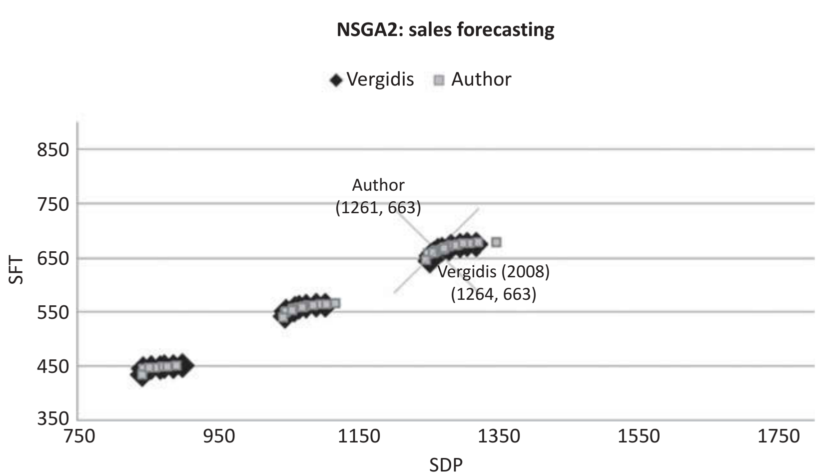

Figure 14. Scenario 1: scatter graph comparison of authors' and Vergidis (2008) results.

Table 7. Result comparison for scenario 2.

Criteria	Vergidis (2008)	Authors' results
Tasks	6	6
Cost	1240	1237
Efficiency	658	667
ANDs	2	2
ORs	1	1
Unique services	SXIP login	Yahoo Maps
Web services	29	48

4.4. *Scenario 2: a comparison between published and authors' results*

By looking at Table 7 and the process graphs shown in Figure 15 [results of Vergidis (2008)] and Figure 16 (authors' results), it may be noted that the authors' results had a higher efficiency than those of Vergidis (2008). In addition, both results have an equal number of tasks and clauses. The results of Vergidis (2008) are more expensive and less efficient than the authors' results (the scatter graph of the results is shown in Figure 17).

4.5. *Scenario 3: a comparison between published and authors' results*

The curve of values obtained by the authors' results is longer and less sharp than Vergidis (2008). This curve is seen in Figure 18. The results are detailed in Table 7 and are characterised by the following observations. Both results have an equal number of tasks but a different number of clauses. The results of Vergidis (2008) NSGA2 are situated nearby the central part of the cloud (shown in Figure 18). The authors' results sketched two extra clouds. The authors' result (shown in Figure 18, detailed in Table 8 and displayed in graph form in Figure 19) has a lower cost than that achieved by Vergidis (2008).

The results described in this section demonstrate the benefit of using an extended web service library with bpo^F. It is also the case that additional new process combinations are created when a greater range of web services are provided to the framework (as evidenced in the scatter diagrams). The three scenarios in this article illustrate the range of processes that may be optimised by this approach.

5. Conclusions

This article explored the optimisation of business processes by providing insights into the use of web services for the development of re-configurable business processes. In particular, the effect of using of an expanded web service library has been investigated. From the case study scenarios featured in this work, it is clear that an expanded library based on a categorisation of common web services can lead to the identification of better processes. In terms of the experiments in this article,

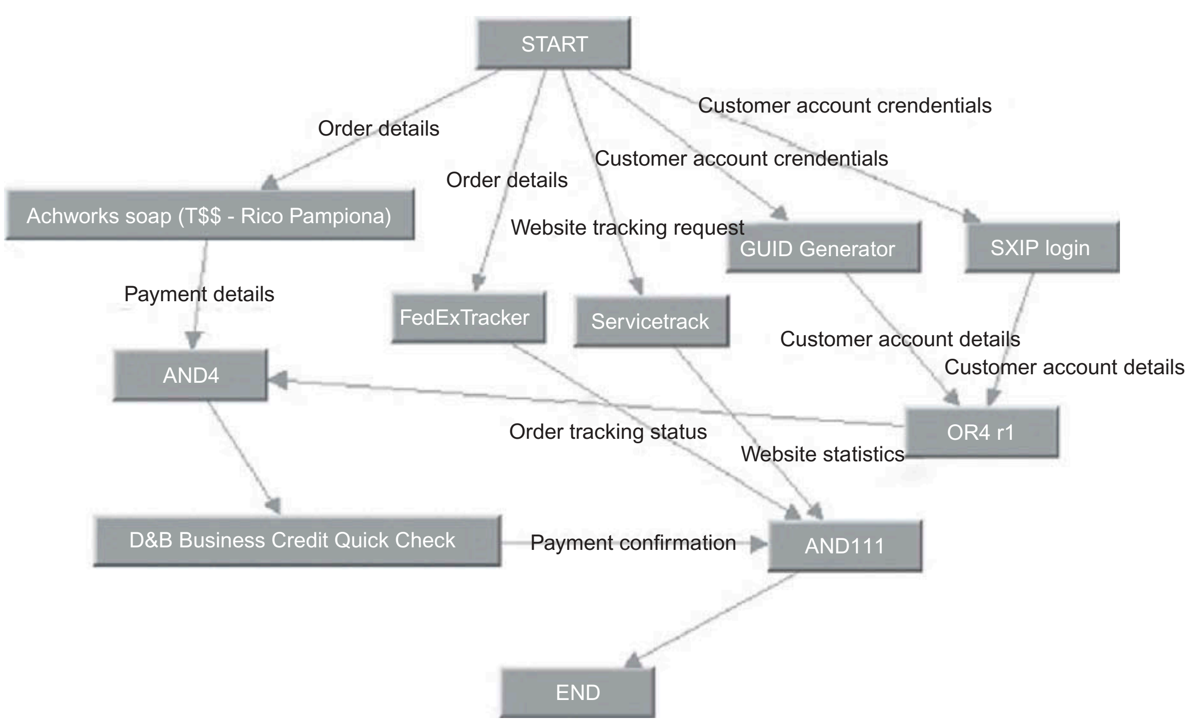

Figure 15. Scenario 2: Vergidis (2008) results.

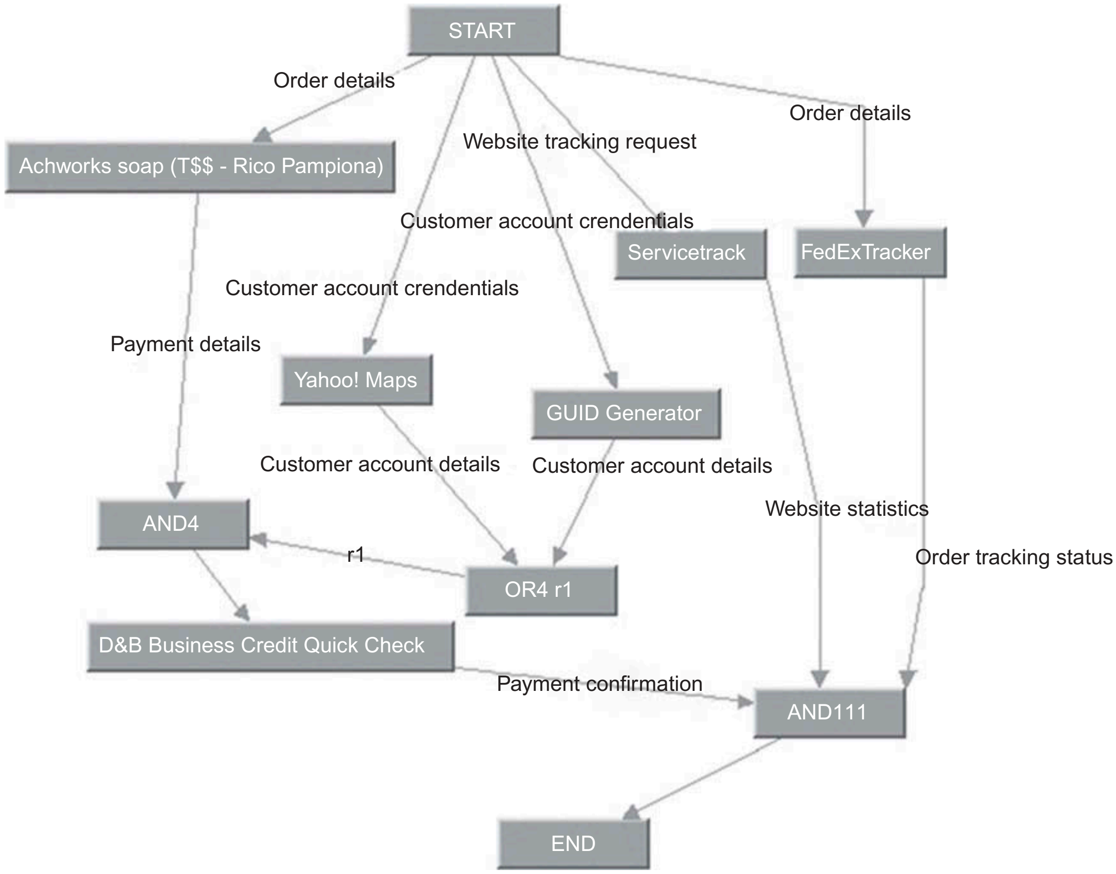

Figure 16. Scenario 2: authors' results.

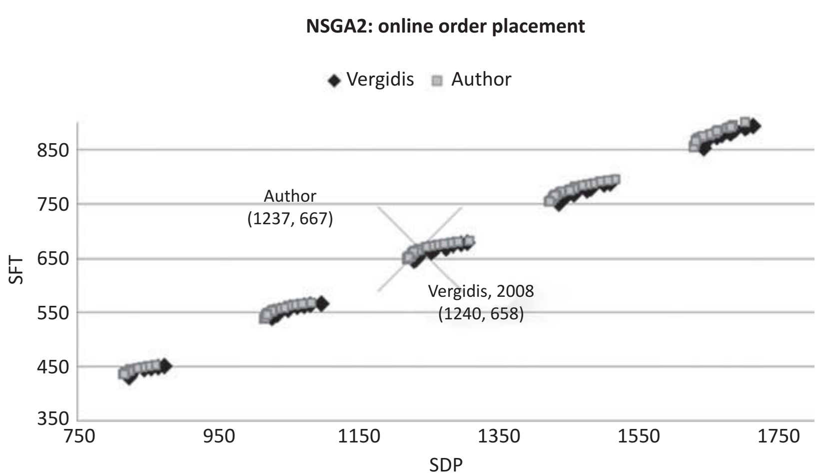

Figure 17. Scenario 2: scatter graph comparison of authors' and Vergidis (2008) results.

processes that have a higher efficiency and lower cost may be identified through the use of the expanded web service library. A categorisation of web services has been provided for the classification of web services used in the research presented in this article. This has aided the selection of web services for use within a process by bpo^F. Observations in this research note that additional result clouds containing new and novel process designs also result from the use of an expanded web service library. It has also been shown that this optimisation approach has particular relevance to the optimisation of processes within the supply chain of a manufacturing organisation.

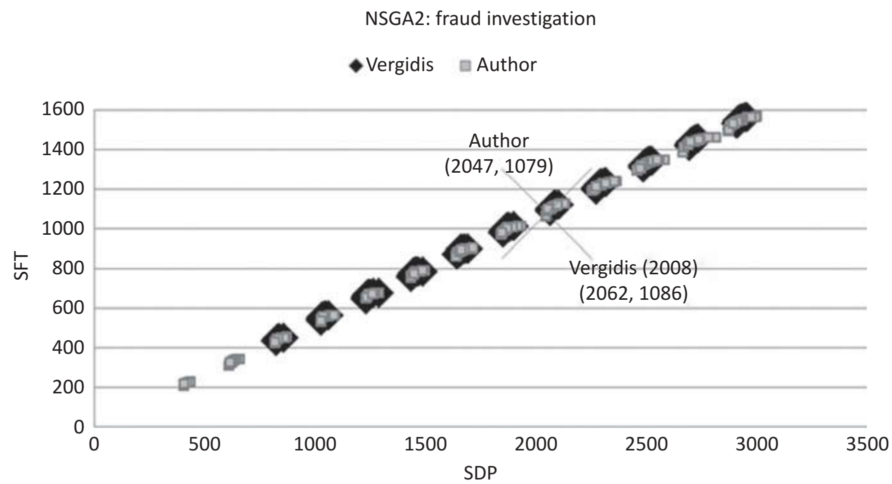

Figure 18. Scenario 3: scatter graph comparison of authors' and Vergidis (2008) results.

Table 8. Result comparison for scenario 3.

Criteria	Vergidis (2008)	Authors' results
Tasks	10	10
Cost	2062	2047
Efficiency	1086	1079
ANDs	0	0
ORs	10	2
Unique services	Drupal authentication	WebservicesX.NET Validate Email
Web services	31	72

As the amount of web services in the market increases, more options will be available, making it difficult and time-consuming to assess competing services. The automated nature of this approach aids the discovery of more efficient processes based on competing web services. To this end further work is still required to standardise the way web services are defined and made available to users. There is also no standard way of determining the true price of using a web service along with the comparative level of efficiency it provides; this would increase the

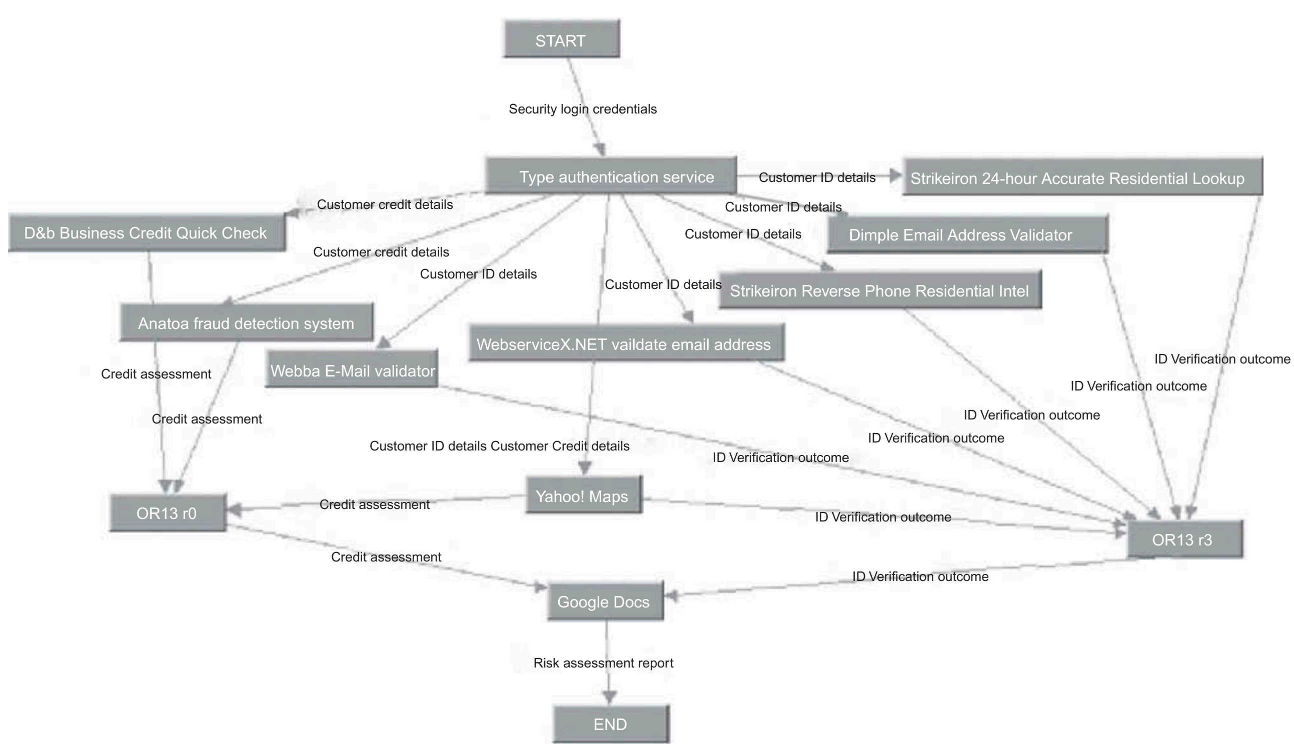

Figure 19. Scenario 3: authors' result.

amount of web services available to the practice of business process optimisation. One solution to this would be an independent ranking of web services through a directory/recommendation site. The ability to identify duplicate (repeated) tasks could also be addressed in future work through the use of an additional technique to differentiate the process execution context of each occurrence. The bpo^F would also benefit from the development of an additional library composed of process templates and sub-sequences. Such a template library would aid the efficient construction of valid sub processes and enable bpo^F to explore a wider variety of solutions. The ability to re-use existing processes, technology and business requirements has great potential in the future.

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