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Review

Adaptive policy framework: A systematic review

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ABSTRACT

This paper presents a systematic literature review to gain an understanding of adaptive policies. This review looks at papers published between 1970 and 2011 and examines the background and trends in this area. Based on the results, we establish a 4-step framework for managing and handling adaptive policies. We also demonstrate gaps in existing literature, the implications to theory and practice as well as avenues for potential future research.

Contents

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1. Introduction

The field of service management has recently evolved to embrace cooperative paradigms where loosely-coupled, user-centric nature of services and diversity of business models require management approaches which can be applied across organizational boundaries (Feeney et al, 2011). In recent years, there have been increasing trends toward cooperative management (Ray and Lewis, 2009) and much research proposes the use of policies to coordinate inter-organizational relationships (Sloman, 1994; Strassner, 2004; Talaei-khoei, et al., 2012). Cooperative environments are generally governed by policies (Zikos and Karatza, 2009), a set of rules designed to guide procedures and workflows, and these procedures and workflows can change frequently, or involve exceptions (Migon, et al, 2010). Therefore, policy-based systems have to deal with unexpected changes and exceptional situations, requiring the original policies to adapt themselves when such situations come to the fore. The dominating view in the literature favours the use of information technology (IT) tools as a means to assist organizations in developing and managing adaptive policies (Lewis et al. 2010).

The concept of policy has been used in a wide range from high level organizational documents to low level business rules. (Strassner and Strassner 2004) divides IT-centric support of policies into business, system, role and administration level policies. Our concept of policy is mostly related to role-level policies as technology-independent mechanisms to control roles' behaviors in cooperative environments.

Not surprisingly, in cooperative environments, complying with policies is required. However, these policies are built keeping the best possible future in mind, and often problems start to arise when these policies are too rigid and designed without considering all possible situations and future uncertainties. When a cooperative role runs into unexpected or exceptional scenarios, any behavior that the role may perform may violate the policy constraints, and the behavior may have to be aborted. However, abortion may not be the best strategy (Lewis et al. 2010). Another option is to deal with the consequences of performing a non-compliant action later (Migon et al., 2010). It thus becomes important to investigate how one should select behavior to have minimum incompliancy, if any behavior that can be chosen does not follow the policy; that is policy adaptation which has been defined in different ways: (a) Adaptation by changing values of policy parameters depending on performance feedback (Lotlikar and Mohania, 2006). For example, Dearle et al. (Dearle et al. 2010) propose a new language-independent adaptable and adaptive policy framework suitable for integration in a wide variety of middleware systems, supporting the construction of adaptive distributed applications. (b) Adaptation by relaxation which means checking non-conformance behavior against an alternative policy derived from the original policy. (Lewis et al. 2010). There exist various studies that have been carried out to assist in the creation of adaptable policies which are capable of changing from the standard operating procedures depending on the environment and situation. Amongst the solutions, one can choose from policies that are aware of the environment under which they operate and can modify themselves based on triggers and events, while others can utilize methods to introduce new or modified policies without affecting the overall system.

This study conducts a systematic literature review of current research that aim at managing situations in which policies need to adapt. The present study develops a framework for policy adaptation that is derived from the methodologies proposed in the literature. The results help us to determine gaps and trends in the existing body of knowledge in this field.

The rest of the paper is organized in the following way: Section 2 discusses the research methodology. Section 3 presents an adaptive policy framework. Section 4 discusses the demographic statistics and gaps from the literature along with the implications and limitations of this study. Section 5 concludes the review and presents scope for future research.

2. Research method

The objective of this study was to conduct a systematic review, which would help us generate a framework for adaptive policies using existing work in this domain. For this to happen, we customized the guidelines for systematic reviews laid by (Kitchenham, 2004) and applied in several reviews such as (Ghapanchi and Aurum, 2011) and (Talaei-khoei, et al., 2012). Kitchenham proposes four steps to carry out a literature review: (a) identification of resources, (b) selection of studies, (c) data extraction and synthesis and (d) data analysis.

2.1. Identification of resources

The first step towards resource identification was recognizing the relevant keywords. This was carried out following the experimental method given by (Dieste et al. 2009). We conducted a broad search on Google Scholar using the term 'policy adaptation'. The first 250 search results were scanned and 'adaptive' and 'dynamic' were found to be the most relevant related keywords for policy deviation.

Once the keywords were determined, four databases – Science Direct, Springer Link, IEEE Xplore and Google Scholar – were searched to find relevant studies in the field. For the initial screening, only titles, abstracts and keywords were considered and the search was limited to studies published between the years 1970 and 2011, both inclusive.

The following search phrases were used while querying each database – e.g. the second search indicated that the article should contain the word 'policy' along with any of 'adaptive' or 'adaption' in its title, keywords or abstract.

- (policy) and (adaptive or adaption).
- (policy) and (deviation).
- (policy) and (dynamic) and (deviation).

The articles were searched over multiple subjects and returned a total of 6355 articles. A full list of databases, subjects and

Table 1
The online databases and subjects.

Database	Subjects	Number of articles	Number of duplicated articles
Springer Link	Computer science, Engineering	470	–
Science Direct	Computer science, Decision sciences, Engineering	479	–
IEEE Xplore	Computing and processing, communication, Networking and broadcasting, General topics for Engineers	2838	145
Google Scholar	Engineering, Computer science and Mathematics	3986	1273
	Total	7773	1418

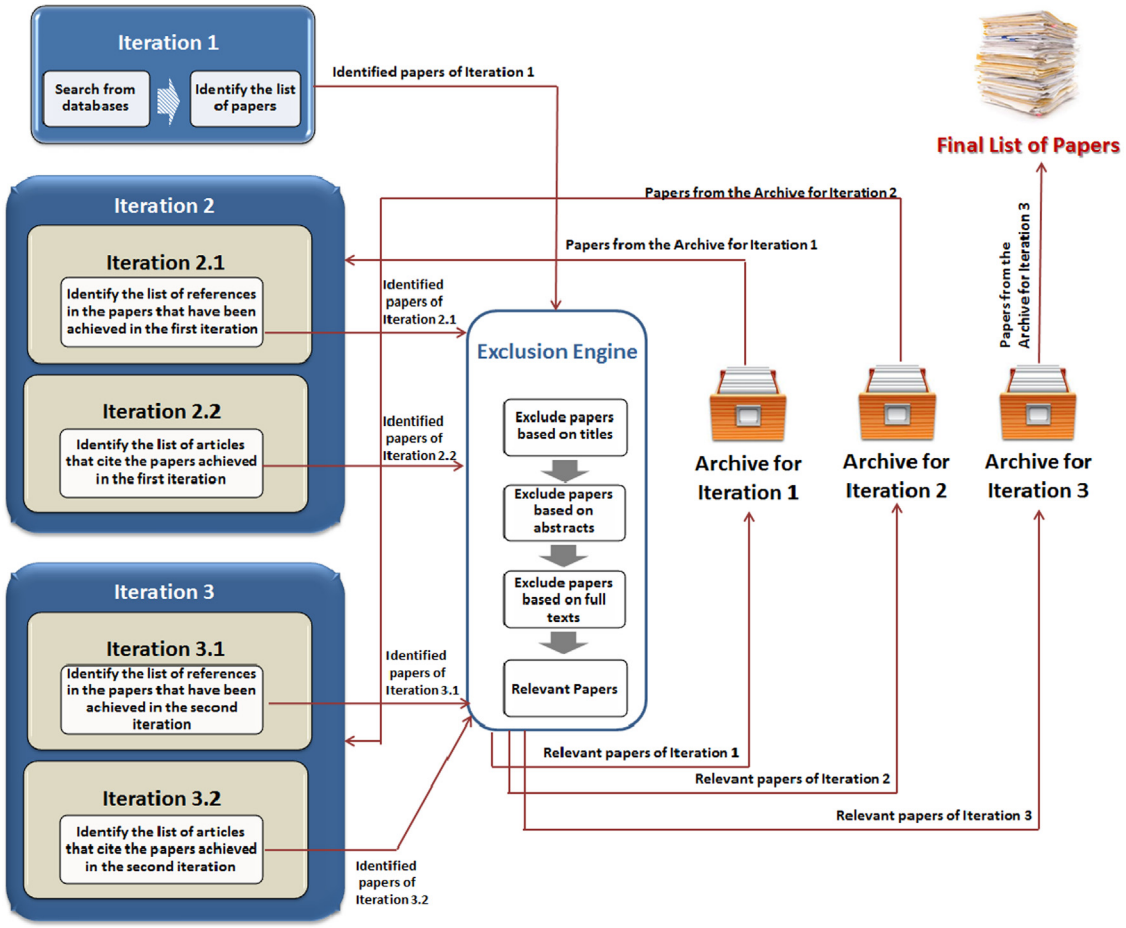

Fig. 1. Selection process.

number of articles is provided in Table 1. In the process of the searching articles, we have found 1418 papers have been duplicated.

2.2. Selection of studies

In this step, the objective is to filter relevant papers from the initial list and exclude the ones not related to "policy deviation". This process is carried out in three iterations as presented in Fig. 1.

The first iteration involved searching for the selected keywords over four databases and excluding papers based on titles, keywords, abstracts and full texts. This removed articles that have one of the following exclusion criteria:

- Did not focus on policy adaptation.
- Discussed only applications of adaptive policies and not the methodological aspects.
- Were in languages other than English.
- Were not in the relevant fields or could not be applied to relevant fields.
- Were not peer reviewed.
- Were not available online.

The second iteration had two sub-iterations: (I) searching on references of the papers found in the first iteration, and (II) searching on papers, which had cited the found papers in iteration 1. This was done using Google Scholar. In each of these two sub-iterations, we ran the exclusion process and excluded papers based on the above criteria. As a result, iteration 2 found 14 relevant papers (eight papers from searching on the references and six papers from searching on the citing papers).

In iteration 3, we have repeated the above process on the papers found in iteration 2. This added six papers to the final list, which four papers were identified by searching on the references and two were from citing papers. As such, the final archive had 43 papers, which confirms the claim stated in (Marchau et al. 2010) for the lack of enough studies in the area of adaptive policies.

2.3. Data extraction and synthesis

In the data extraction and synthesis step, the key details from the selected papers were obtained. In this review, the information extracted was divided into two groups: (1) methods, where the different methodological approaches of policy adaptation are synthesized and (2) demographics of the published works, e.g. the year of publication.

2.4. Data analysis

The data analysis stage involved extracting the terms and definitions used in the final list of selected papers, eventually forming the primary list of methods used in these studies. It broadly categorized what problem each method was trying to solve. The analysis process is depicted in Fig. 2.

Once the terms and methods used in the papers were categorized, the following points were discovered (see Table 2):

- Policy in social theory is a generalized expectation of behaviors. Policies in this perspective are a set of social rules that

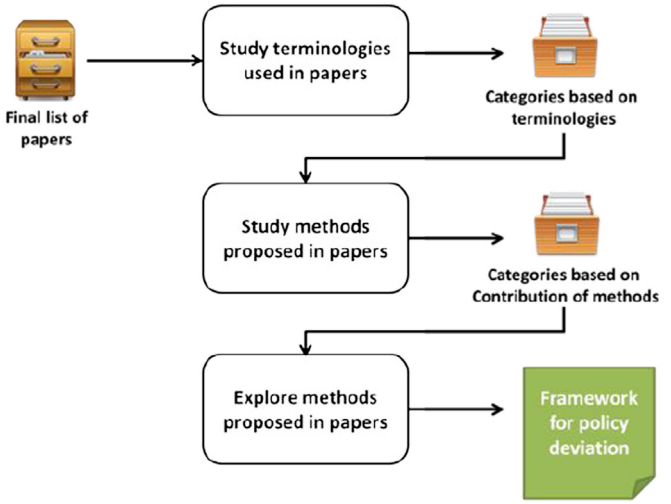

Fig. 2. Data analysis process (Talaei-Khoei et al., 2012; Ghapanchi and Aurum, 2011).

Table 2
Categorization based on terminologies and methods.

Categories identified by exploring terminologies proposed in the articles	Categories identified by exploring methods proposed in the articles
• Stage setting • Policy setup • Policy design and implementation • Policy monitoring • Continuous improvement	• Policy requirement gathering • Policy modeling • Event based policy adaptation • Runtime policy reconfiguration • Agent learning • Policy ranking

are designed by the community of individuals and can be changed or modified if required.
- Policy from the perspective of legal theory is a set of constraints that restricts action to certain behaviors and are designed by an authority. Such policies are generally not flexible.
- In order to have an environment that supports adaptive policies, careful planning and policy set-up is required. This can involve taking into account historical factors, organizational workflows, future possibilities, uncertainties, etc.
- Policies are designed according to a policy definition. In order to support adaptation, policies should be designed to detect and handle environmental changes.
- Policy maintenance can be carried out dynamically during runtime without stopping the system.
- Policies can be monitored automatically using environmental triggers or pre-set conditions.
- Policies can be modified automatically based on events and conditions.

Finally, taking the above points into consideration, a classification of methods for policy adaptation i.e. an adaptive policy framework was derived.

3. Policy adaptation

Walker et al. (Walker et al. 2001) divides the adaptive policy development process into two phases, the thinking phase and policy implementation phase. The thinking phase mainly involves understanding the requirements and key components of the policy along with developing the rules which the policy

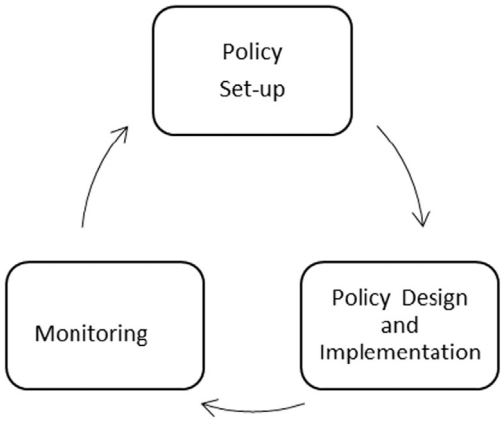

Fig. 3. Phases in adaptive policy management process.

instrument must perform. The policy implementation phase on the other hand involves the actions that are performed once the policy instrument is put in practice. Similarly, Swanson et al. (Swanson and Bhadwal, 2009) describe the adaptive policy cycle in three stages: (a) policy set-up, (b) policy design and implementation, which are analogous to the thinking and implementation phases described earlier and (c) monitoring, which involves continuously monitoring and evaluating the performance of the policy and changing it according to the evolving requirements (Fig. 3).

Our review finds that the techniques found in the literature for adaptive policies belong to at least one of the three stages amongst: (a) policy set-up, (b) policy design and implementation and (c) monitoring. based on the retrieved papers, we have also categorized the existing body of the research in this area, which give more details for what it needs to be done in each step. This systematic review provides insight into the steps proposed by Swanson and Bhadwal (2009). In the following section, we present our findings in terms of the methods in computer supported co-operative work (CSCW) that can be used in each steps of the policy adaptation process (Fig. 3). Tables 3–6 provide brief descriptions of the methods as well as the key differences in either the methods or the steps. This follows by an extended framework for Swanson's proposal (Swanson and Bhadwal, 2009) from CSCW perspective. The framework has been extracted by the existing literature to support policy adaptation.

3.1. Policy setup

Policy making is about the future (Walker et al. 2001) and policy set-up is the first step towards creating policies which are capable of adapting themselves in dynamic and changing environments. Swanson (Swanson and Bhadwal, 2009) lays down the steps involved in the policy set-up stage for policy makers interested in creating adaptive policies (Fig. 4). This involves determining policy goals and requirements, identifying indicators that affect policy performance. Once the goals and factors are determined, policy makers need to determine possible scenarios where the key factors that affect the policy performance are affected and test different policy options to minimize the negative effects.

Marchau et al. (Marchau et al. 2010) terms the initial process of gathering policy requirements, goals and constraints as stage setting and Swanson (Swanson and Bhadwal, 2009) suggests multi-stakeholder deliberations in order to generate discussions and understand the policy goals and requirements from different perspectives. Marchau et al, (2010) and Walker et al. (2001) propose that to begin the process of creating adaptive policies, at the outset, a basic version of the policy must be chosen. This policy

Tabl 3
Policy set-up.

Objective	Methods	Outcomes
Determine policy requirements, goals and constraints	Swanson et al. (2010) describe **Multi-stakeholder deliberation** as a collaborative effort that involves using inputs from a variety of stakeholders who are directly affect or are affected by the policies. This allows the policy to be viewed from different perspectives before a final informed decision is taken.	**Goals Objectives**
	Walker et al. (2001) suggests a two stage process for creating adaptive policies – a **thinking stage** and an implementation stage. The policy setup is carried out in the thinking stage where the structure of the policy is assembled and key uncertainties, actions and signposts are discovered.	**Policy constraints**
	Marchau et al. (2010) put forward an adaptive policy making process that begins with **stage setting** where the policy constraints, objectives, definitions of success and options sets are recognized by the policy makers before assembling the basic policy with necessary conditions for success and policy actions.	**Key uncertainties**
Identifying key policy factors	Policy ranking allows policy makers to prioritize actions while making strategic decisions when faced with uncertainty.	**Ranked policies**
	De Kort and Booij (2007) presents methods for **ranking policies and analyzing uncertainties** and applies them in a pilot Decision Support System (DSS) for flood control in the Red River basin in China and Vietnam.	**Key influential factors**
	Dai and Goldsmith (2010) studies the problem of *k best policies* in a Markov Decision Process and provides two algorithms to find the *k*th best policies to assist in the ranking of policies.	
	Swanson et al. (2010) and Migon et al. (2010) suggest group deliberations to identify key factors that affect the policy.	
Determining future scenarios and policy options	Migon et al. (2010) suggest a collaborative process of detecting possible policy deviations through **story-telling** among people directly involved with the policy where they discuss various scenarios of policy deviations based on experience and using the **Theory of Constraints** as a language to represent them.	**Vulnerabilities**
	Swanson and Bhadwal (2009) discusses **Forward looking analysis** that allows stakeholders to look at policies retrospectively, prospectively and comprehensively. It involves identifying key factors that affect policy performance and how the factors can change with time.	**Contingency plans**
	Marchau et al. (2010) put forward a dynamic/adaptive process which recommends analyzing the policy for vulnerabilities along with **mitigating** and **hedging** actions for susceptible situations. They also suggest determining signposts and triggers to identify potential exceptional situations.	**Mitigating actions**
	Walker et al. (2001), Swanson and Bhadwal, (2009), Marchau et al. (2010), all recommend having contingency plans in place in case of a completely unexpected event.	**Hedging actions**
	Additional papers: Holling (1978), Adler and Haas (1992), Rondinelli (1993), Bankes (2002), Lim et al. (2005), Pahl-Wostl et al. (2008) Swanson and Development (2009), Lempert and Groves (2010), Moench (2010).	

Table 4
Policy design techniques.

Approaches	Methods	Techniques
Design automatic built in policy adjustments	Malandrino et al. (2010), put forward a framework called MIMOSA that uses context awareness to change the behavior of a policy rule in a ubiquitous computing environment depending on the context of the user and the device.	**Context aware**
	Lotlikar and Mohania (2006) present a simple way of defining adaptable policies using the standard Event-Condition-Action model where policies dynamically alter themselves based on predefined conditions when an event is triggered.	**Event based**
	Biskup (2011) present a method of using historic information just as past queries to dynamically modify current policies.	**History dependent**
	Couch et al. (2007) presents a method that allows an agent to completely control the sequence of sets of promises to which it commits with another agent, and allows agents to adapt to changing conditions by making short-term bilateral agreements.	**Message passing**
	Whitehead and Ballard, (1991) presents a decision system that overcomes the problem of perceptual aliasing where an agent's internal representation confounds external world states. This results in a control architecture that can learn how to solve a task as well as focus its attention to collect necessary sensory information.	**Trial and error**
Design semi-automatic built in policy adjustments	Karus and Dumas (2007) present a case study where they use combination of techniques to semi-automatically enforce policies and guidelines using xslt-req on community-built presentation components in a web portal.	**Transformation rules**
	Koyanagi et al. (2005) describes a method for runtime policy reconfiguration without affecting the rest of the system by defining policies as configuration sets.	**Runtime policy reconfiguration**

should then be analyzed for vulnerabilities and anticipatory actions should be determined for each of these.

Once the policy goals are set up, the next stage requires identifying the main factors that affect the policy performance and planning for possible future exceptions. Migon et al. (2010) suggests a collaborative method of detecting possible policy exceptions and key policy factors through story-telling among participants directly involved with the policy where they discuss various scenarios of policy exceptions based on experience. Dekort and Booij (2007) provides a method for ranking these factors which can help policy makers design strategic selections among the different measures while planning for possible exceptions and future uncertainty. Albeit adaptive policies are supposed to handle both expected and unexpected situations, it is impossible for policy makers to take into account every possible scenario and for this reason and therefore Walker et al. (2001) and Swanson and Bhadwal (2009) recommend having contingency plans along with a specification of conditions under which the entire policy should be reconsidered. The various techniques proposed in the literature for the policy setup phase are described in Table 3.

3.2. Policy design and implementation

Once the policy requirements are established at the setup stage, policy makers can start designing the policies for implementation. This phase can also be called the policy modeling phase. Various techniques have been developed on how to design adaptive policies and the policy designers must make the decision of choosing the most appropriate design based on the requirements from the setup stage.

A review of the literature shows that event-driven policies that adjust themselves based on context, triggers and signposts are most commonly used (Marchau, 2010). Swanson et al. (Swanson

Table 5
Policy implementation techniques.

Objective	Methods	Techniques
Develop Representation languages and methods	Mcilraith et al. (2001)) presents a new semantic web markup language in the DAML family, enabling the discovery, execution, composition and interoperation among a number of agent technologies for automated web services.	**Message passing**
	Schulte et al. (2009) introducesWS-Re2Policy 2.0, a language which combines WS-Policy-based policy assertions with information regarding deviation handling. It is a policy language to describe requirements and handing deviations through defined reactions.	**Event based**
	Samuel et al. (2007) introduces X-enterprise, an XML based policy language for context sensitive network management.	**Context sensitive**
	Moore (2000) describes a system for defining conversation policies that allows conversants to exchange representations of how they use messages to get things done. The study also shows how to accept deviations from these policies and dynamically combine policies.	**Message passing**
	Zargayouna and Amara (2006) provides a solution for mobile agents that work in continuously changing environments using formal ontologies to model the agent's execution context.	**Ontology**

Table 6
Policy monitoring.

Objective	Overview	Technique
Review policy performance	Swanson et al. (2010) suggest carrying out **formal reviews** regardless of how well a policy performs. This process helps detect emerging issues that might affect the policy performance in the future.	**Formal review guidelines**
	Busenberg (2001) shows how learning arrangements and focusing events can play roles is policy change.	**Learning processes**

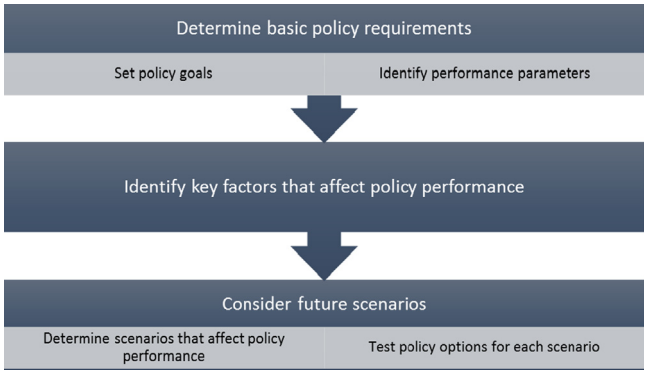

Fig. 4. Stages of policy set-up (Swanson and Bhadwal 2009).

et al., 2010) refer to such techniques as built-in policy adjustments and categorize them into two types—automatic and semi-automatic. When the policy conditions and anticipated events are well understood, fully automatic policy adjustments are used. Some examples of fully automatic policy adjustments include (Malandrino et al., 2010), who put forward a framework called MIMOSA that uses context awareness to change the behavior of a policy rule in a ubiquitous computing environment depending on the context of the user and the device. Similarly, (Lotlikar and Mohania, 2006) present a simple way of defining adaptable policies using the standard Event-Condition-Action model where policies dynamically alter themselves when some event is triggered.

On the other hand, when the anticipated events are not so well defined, semi-automatic policy adjustments are used. Karus et al. (Karus and Dumas, 2007) present a case study where they use combination of techniques to semi-automatically enforce policies and guidelines on community-built presentation components in a web portal. Biskup (2011) and Whitehead and Ballard (1991) take a different approach and present methods that facilitate policy changes based on a historic information like past queries or trial and error. Table 4 summarizes the different studies that discuss policy design.

There are also studies that introduce ways to implement adaptive policies. Schulte et al. (2009) present WS-Re2Policy 2.0, a language which combines WS-Policy-based policy assertions with information regarding deviation handling while Samuel et al. (2007) introduce X-Enterprise, a policy language for policy based network management that allows creation of context sensitive network policies. Mcilraith et al. (2001) present a new semantic web markup language in the DAML family, enabling the discovery, execution, composition and interoperation among a number of agent technologies for automated web services. (Zargayouna and Amara, 2006) provide a method to model a mobile agent's execution context in continuously changing environments using formal ontologies. Table 5 provides brief summary of implementation methods along with their differences in the techniques that they use, which map them to different applications.

3.3. Policy monitoring

As mentioned earlier, even in the best case scenario, it is nearly impossible for the policy designer to consider all possible futures and even when there is no need for policy adaptation due to environmental factors, organizational goals can change or need updating over time (Koyanagi et al., 2005). Swanson et al. (Swanson and Bhadwal, 2009) recommend carrying out formal reviews even in cases where the policy performance is satisfactory as they can help address emerging issues and trigger important policy adjustments while Busenberg (Busenberg, 2001) presents learning mechanisms to assist changing the policies.

Table 6 summarizes the different studies that discuss policy monitoring and improvement.

3.4. Adaptive policy framework

According to what has been proposed by Swanson and Bhadwal (2009), we find that the process of creating and maintaining adaptive policies is carried out in three main steps – (i) policy set-up, (ii) policy design and implementation and (iii) policy monitoring and improvement (Fig. 5). In what have been presented above, we have supported the Swanson proposal for policy adaptation by CSCW literature. In this section, based on our

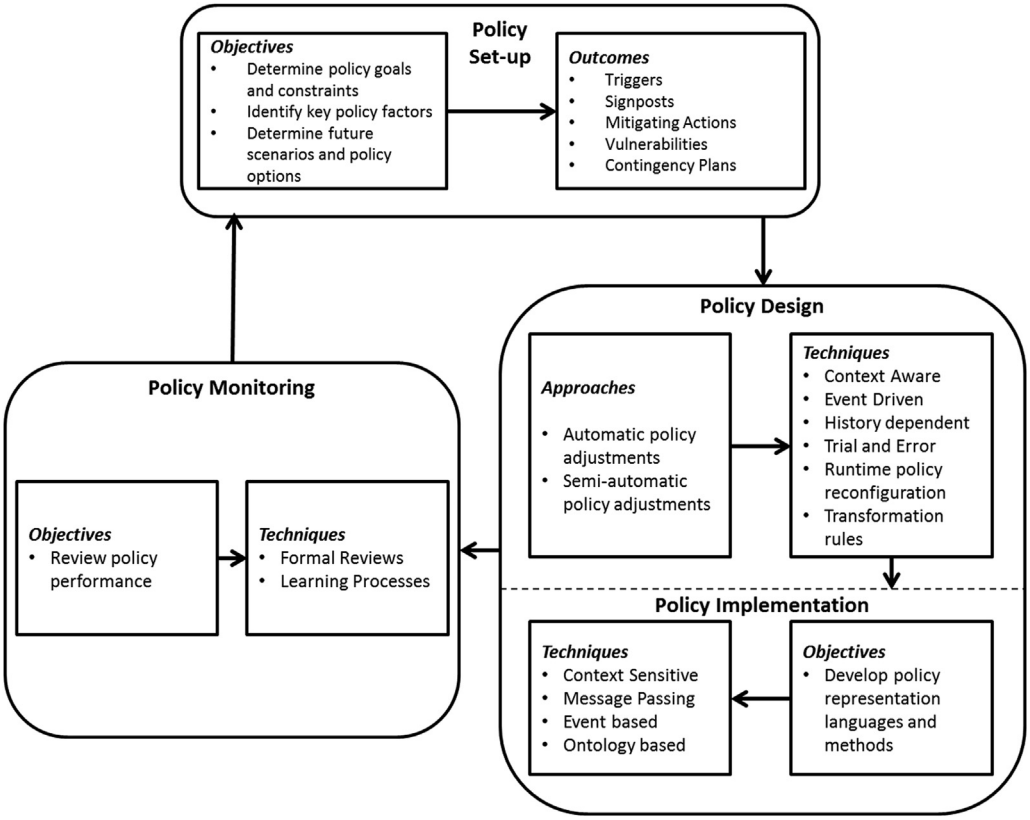

Fig. 5. Adaptive policy framework.

Table 7
Evaluation of methods.

	Policy setup			Policy design and implementation			Monitoring
	Determine policy requirements goals and constraints	**Identifying key policy factors**	**Determining future scenarios and policy options**	**Design policies with automatic built in adjustment**	**Design policies with semi-automatic built in adjustment**	**Develop Representation languages and methods**	**Review policy performance**
Adaptation by changing policy parameters to match situational demands (Lotlikar and Mohania, 2006)	✓	✓	✓	✓	✓	✓	✓
Adaptation by checking non-conformance behavior against an alternative policy derived from the original policy (Lewis et al. 2010)	✓	✓	✓	✗	✗	✓	✓

systematic review, we provide more details for this proposal as well as methods that can be used in each stage.

The aim of the policy set-up phase is to determine the policy goals, constraints and performance factors in order to understand the policy vulnerabilities and in turn develop triggers, signposts, mitigating actions and contingency plans. Using these outcomes from the policy setup phase, policy makers choose automatic or semi-automatic methods such as context awareness, event triggers, history dependence, etc. to design adaptive policies and utilize relevant tools and languages to implement them. Once the policies are put in practice, their performance need to be continuously monitored and reviews must be carried out to learn from the outcomes of these policies to further improve them. Depending on the outcomes of these reviews, policy makers can choose to either update certain parameters to optimize policy performance or use the lessons learnt to reconsider the policy objectives and re-design the policies completely.

Thus the adaptive policy framework presented in this section provides a step by step guide for anyone interested in creating and maintaining adaptive policies.

4. Discussions

In this literature review, we have seen the various processes involved in the setup, design, and monitoring of adaptable policies. We have also presented a 3-step adaptive policy framework that describes the overall process and allows one to quickly point to the relevant stage. In the present study, having systematically reviewed the methods in policy adaptation, we have

Table 8
Comparison of our framework with the work of Walker et al (2001).

Similarities	Differences
– Both frameworks lay down the steps to create adaptive policies. – Both focus on identifying vulnerabilities and mitigating actions. – Both frameworks divide the adaptive policy making process into phases – Both suggest reassessing and updating the policies.	– Walker's framework focuses more on the processes of creating adaptive policies, whereas our framework focuses on both the process as well as the various techniques available to assist in doing so. – Walker suggests reassessment be carried out when certain conditions are triggered which is more cost efficient. However, the framework presented in this paper suggests policy monitoring be carried out periodically regardless of the performance of the policy, which is supposed to provide better adaptation. – The framework presented in this paper includes an implementation stage which is not present in Walker's framework.

avoided unintended biases that often happen in literature reviews when researchers impose their preset mind in the selection of particular type of papers. The application of a clear search strategy and a systematic process of finding relevant studies in order to create the adaptive policy framework add credibility to the entire review process and make the results repeatable and transparent to the reader. The process not only helps to identify the gap in the existing body of literature in policy adaptation, but also reasonably ensures the reliability of the claim.

In this section, we shall be discussing the overall publication statistics of the final list of papers, identified gaps in literature, the implications to theory and finally the implications to practice.

4.1. Evaluation of methods

As discussed in our introduction, policy adaptation can be defined in two ways: (a) adaptation by changing policy parameters to match situational demands (Lotlikar and Mohania, 2006) and (b) adaptation by checking non-conformance behavior against an alternative policy derived from the original policy (Lewis et al., 2010). In the previous section we discussed the various stages involved in creating and handling adaptive policies and also presented a framework for that. In Tables 3–6 we have categorized the methods used in each stage of the framework. In this section, we provide criteria through which literature in adaptive policies can be evaluated according to the definition of adaptation.

In order to take the step forward into gap analysis, in Table 7, we have evaluated the support of constructs for the framework given in Fig. 5, against our original definition of adaptation. We found the methods proposed in CSCW, have been heavily focused on adaptation by policy change i.e. Lotikar's perspective (Lotlikar and Mohania, 2006). However, this is only possible when we are able to change the policy in run-time and there several cases discussed in the next section that we are basically not able to change the policy. In such cases, the solution for adaptation can be described by Lewis et al. (2010). Although Lewis et al. (2010) have presented an idea to solve this problem, the work lacks a sufficient level of details and implementation. This will be discussed in Section 4.2. In Table 7, we have also found that the methods proposed for policy setup, implementation and monitoring can be still reused in to relax the policy in order to have an adaptation. However, the methods in design will not be applicable because relaxation does not change the policy, but relaxes that.

4.2. Comparison with a similar framework

In this section, we compare the adaptive policy framework derived from this literature review in Fig. 5 with the work of Walker et al. (2001), which has been applied in transport policies by Marchau et al. (2010).

Walker et al. (2001) has proposed a framework to clarify the process in which the adaptive policies can be created to cope with uncertainties of environments. The approach focuses on a process that can be triggered by the changes in the environment. The changes can be identified as information becomes available in the environment. The biggest innovation in this work is a cost-efficient pragmatic approach to monitoring. In this framework, the monitoring only occurs when certain conditions are triggered (Table 8).

4.3. Gap analysis

In this section, we provide two types of gaps that we could have found in the literature: (a) the gap to support policy relaxation, and (b) the limitations and avenues for future research identified by retrieved studies.

4.3.1. Support for policy relaxation

As we mentioned in Section 4.1, the framework presented in Fig. 5 can provide support for policy adaptation in terms of change of the policy (Lotikar, 2001), but the litrature has largely ignored the adaptation by relaxation of the policy (Lewis et al., 2010). The problem arises when we understand that the approach presented by Lotikar (2001) can only be applied in a particular type of polices that we are able to change in run-time. Here, we provide more details on this issue.

Verhagen, 2001 describes policies from various perspectives, namely – policies from the social theory perspective, policies from legal theory perspective. The social theory (Verhagen, 2001) states that a cooperative role complies with policies because it is rational to do so and because that is what others expect from the role. Therefore, policy in the social theory can be described as a generalized expectation of behaviors. Policies from in this point of view are a set of social rules that are designed by the community of cooperative roles and can be changed on the go, thus they can be adaptable. The definition of policy adaptation specified by Lotlikar et al. (Lotlikar and Mohania, 2006) where policy parameters are changed depending on performance feedback best describes these types of adaptable policies. On the other hand, legal theory looks at policy as a sense of duty (Verhagen, 2001) and that a cooperative role complies with a policy because of the authority issuing the policy. Policy in this perspective is a set of constraints that limits behaviors. Since these policies are designed by an authority, they cannot automatically be changed. When exceptional situations do occur, one has to decide what action must be performed to have minimum incompliancy from the specified policy. The definition of policy adaptation defined by Lewis et al. (Lewis et al., 2010) where non-conformance behavior is checked against an alternative policy derived from the original policy best describes policy adaptation when legal policies are in place.

Table 9
List of limitations in current literature.

Contribution	Migon et al. present an approach for elicitation and discovering problems in business processes that combines the technique of group storytelling with the theory of constraints
Limitations	The groupware tool used has limited support for the representation stage of the method and better support is required to reduce the ambiguity of the knowledge collected. Alternatives to explicitly represent causal relations by storytellers are desired.
Contribution	Lotikar et al. show how adaptive policies can be useful for Information Lifecycle Management and presents a method for performing policy adaptations where policy parameters are adjusted based on operational variables (sensors).
Limitations	In an event of over correction or under correction of sensor values, alarms are raised to minimize damage. Automated correction of these situations is not practicable because it requires a model of system behavior.
Contribution	Koyanagi et al. describes a method for runtime policy reconfiguration without affecting the rest of the system by defining policies as configuration sets.
Limitations	BPM systems should not only to provide the runtime mechanisms to business users but also support the designing and deploying business policies. The authors consider this to be future work.
Contribution	Karus et al. present a case study where they use combination of techniques to semi-automatically enforce policies and guidelines on community-built presentation components in a web portal using xslt-req.
Limitations	xslt-req could be extended to support the specification of rules based on patterns or XPath expressions to make it more applicable. The verification methods that use xslt-req assumes a rigid document base structure
Contribution	**Biskup** presents a method of using historic information just as past queries to dynamically modify current policies.
Limitations	Suitable combinations of the view-based approach and the policy adaptation based approach needs to be found in order to achieve the best possible efficiency for specific situations;
Contribution	Couch et al. presents a method that allows an agent to completely control the sequence of sets of promises to which it commits with another agent, and allows agents to adapt to changing conditions by making short-term bilateral agreements.
Limitations	The most efficient ways to compute the operative promises need to be evaluated. Evaluations must be done to determine if the operators proposed in this method are the most efficient.
Contribution	Nunes et al. models a patient admission system as a Markovian decision process to generate an optimal admission control policy that effectively utilizes available resources
Limitations	Dimensionality is the most serious limitation is this model .The small-sized example configuration comprises 5765 possible states, which generate, 482,504 possible transitions among states with no null probability. The numbers will increase drastically in real life situations and thus requires further evaluation.

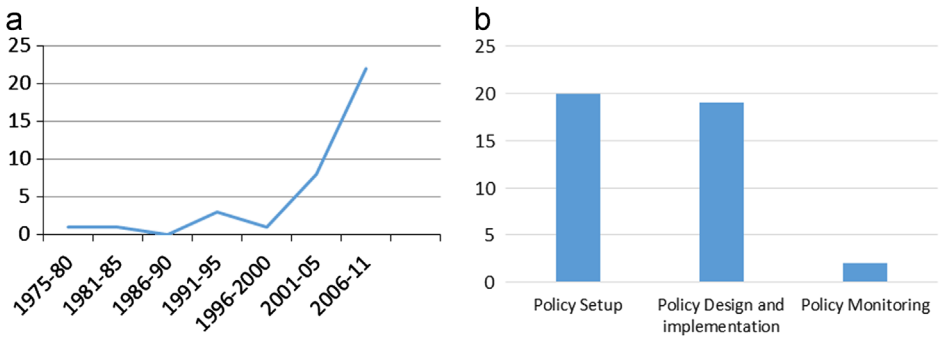

Fig. 6. Demographics. (a) Distribution of the number of papers published on the topic of policy adaptation and (b) distribution of the number of papers published for each phase of policy adaptation.

As seen from the framework derived from the literature, research in computer supported cooperative work mainly focuses on policies as behavioral rules via social perspective. Therefore, policy deviation from most research in IT-centric policy support is typically about change in the social policies. The analysis of the papers shows that while there are studies done on the techniques of creating adaptive policies in IT-centric support for policies, all of them require redefining their existing policies to make them capable of adaptation. But there can be cases where shifting from policies might be impossible i.e. policies built on the legal theory. For policies created according to the legal theory, the authorities, i.e. policy makers and stakeholders, are the ones who can decide whether there is a need for an action that would violate an existing policy when an unforeseen scenario arises. Also, once it is decided that there exists such a need, a decision must then be made as to whether it would be better to stick to the existing policy and abort the action or to ignore the policy and choose a behavior that has minimum non-conformance from the specified policy, dealing with the consequences later. While Lewis et al. (Lewis et al., 2010) do present a brief idea on how to handle this type of policy adaptation, their proposal lacks of enough details to be implementable. Thus, there are currently no definitive methods in the literature that assist users in doing so.

4.3.2. *Limitations and avenues of research presented by studies*

In addition to what we have presented in the previous section, we have presented the limitations and open directions for future research, which have been identified by the retrieved studies. This is presented in Table 9.

One common limitation mentioned in a few papers (Mingon, 2010; Schulte et al., 2009; Karus and Dumas, 2007; Moore, 2000) is that not enough evaluations have been conducted to test the applicability of the proposed methods in real life. Future researchers can therefore conduct studies to evaluate which of the methods presented in the literature are most applicable in practice.

4.4. *Demographic statistics*

In this section, we discuss the demographic statistics of the final list of selected papers. Fig. 6a depicts the distribution of the number of papers published on the topic of policy deviation over

periods of five years since 1980, since there was no relevant paper identified from 1970 to 1975.

The figure demonstrates a clear increase in publications since the year 2000, which shows a greater attention in research for policy adaptation in last decade. Fig. 6b depicts the number of papers published in each of the three categories given in adaptive policy framework. It can be seen that most of the literature focuses on policy setup and policy design while there are very few publications for policy monitoring. The limited number of studies in policy monitoring motivates researchers to work in this field.

We have also found that among then search engines that we have been using, Google Scholar and IEEE Xplore contain most of the papers i.e. Google Scholar had 1273 and IEEE Xplore had 145 duplicated papers. So, as practical recommendation to researchers working in this area, we can say that if they are looking for a quick review of the literature, we suggest Google Scholar and IEEE Xplore. However, we admit that the best practice would be exploring wider range of the search engines.

4.5. Implications to theory

Policies are nothing but a set of rules that defines a course of action. While research in IT-support applications for policies pays great attention to social policies as rules designed by the community of cooperative roles, the adaptive policy framework given in this paper presents a framework to illustrate the steps involved in handling adaptive policies.

This literature review adds to the existing body of knowledge by bringing together published works on policy adaptations and categorizes them in a logical manner for other researchers interested in this field to get a quick overview of all the work that has been carried out over the last four decades.

Another merit of this framework is to clarify the lack of definitive methods in handling policy adaptations when IT-centric applications adopt legal policies rather than social policies. The methods proposed in the framework fall short of addressing legal perspective because of difficulties that exist in changing such policies. This is also mentioned by Dieste et al. (2009). However, to the best of our knowledge, there is no definitive attempt in addressing this problem.

4.5.1. Theoretical support

The Adaptive Policy Framework can be described using traditional perspective of systems; that is the general system theory (GST) (Skyttner, 2006). However, the identified gap for policy adaptation from the legal theory perspective refers to typical drawback of GST when the system cannot be modified.

The basic assumption of GST is that it is possible to separate the internal components and actions of the system from external changes; otherwise, it not possible to see whether the changes in the system behavior are because of the internal changes and decisions or because of the external changes from the environment. This implies that the system can be conceptually isolated from its surroundings and in case of any changes in characteristics of the system; it must be responsive to change the system descriptions.

Looking to the situations that policies cannot be complied because the policy system suffers from the changes in the conditions, the feedback loop to modify the policy description must be deployed. This feedback loop includes four steps: (a) change of variables based on the new identified values in the system, (b) defining new characteristics according to the modified variables, (c) modification of the system and (d) monitoring the system. This perfectly supports the four steps for policy deviation given in the proposed framework as (a) setup, (b) design, (c) modification, and (d) monitoring.

This interpretation can only be valid if policies are defined as characteristics of the system, but entering the legal policy domain; we discover that this assumption is no longer valid and policies are more like constraints on the behavior of the system. In such cases, the feedback loop of the general system theory can only change the way the system applies the policies. However, how this can be utilized has remained as open question, as it is identified in the gap analysis.

4.5.2. Applications in current policy research

The research in IT-centric policy support has been assuming the compellability of policies. For example the policy systems in Sloman (1994), Strassner and Strassner (2004) and the policy-based awareness management framework given by Talaei-Khoei et al. (2011b) are designed in regard to the fact that the system is able to comply the policies. The present framework in this paper can relax this assumption and guide researchers to take certain steps with specific method, in order to make policies more flexible.

Additionally, handling policy exceptions are noted as gaps in other studies such as Talaei-Khoei et al. (2011a), Lewis et al. (2010) and this systematic review can act as a starting point to answer such gaps.

4.6. Implications to practice

Policy management is a topic which has practical implications in organizations and businesses. The Adaptive Policy Framework presented in this study can be useful for organizations which are trying to create and implement adaptive policies in order to handle the policy exceptions. The intended audiences for Adaptive Policy Framework are organizations wishing IT solutions to incorporate adaptive policies. Such organizations can use this framework to outline the steps for utilizing adaptive policies by using the various techniques provided under each of these stages. Readers wishing to explore proofs of concepts for the need of adaptive policies in real life scenarios should refer to Walker et al. (2001), Marchau et al. (2010), Swanson et al. (2010), Carey and Carville (2003).

4.7. Limitations

As is the case with almost any systematic literature review, this paper has a few limitations that must be kept in mind. Firstly, any systematic review is limited by the keywords that are chosen. Poor key wording in the databases might lead to some studies not being identified, however, the method proposed in Dieste et al. (2009) was utilized to ensure the most relevant studies were included for the review. Also, full text content of some of the studies identified was not available online and these were ignored due to time constraints. In addition to that, the present work only looks at publications between 1970 and 2011.

5. Conclusion and future work

In today's rapidly evolving world, adaptation is the key to success, be it for an organization, business or individual. Organizations are generally heavily dependent on policies for their functioning and it can be an expensive affair to break and change policies every time a exception from these policies is required. An alternative solution to this problem is to develop and deploy policies that are able to adapt themselves into different forms as and when required without significantly affecting other

processes. In this literature review, we analyze various studies focusing on policy adaptation and obtain the steps that are required for creating, designing and managing adaptive policies. We present a 5-step adaptive policy framework that reflects these steps. The steps are policy set-up, policy design, policy monitoring, policy modification and policy maintenance. In terms of contributions to the theory, this paper gathers published works on policy deviation and allows researchers to find possible avenues for future studies in this area. On the other hand the implications to practice are that policy makers looking to create adaptable policies can find suitable techniques to do so by using the adaptive policy framework as a guide.

Looking into the future, researchers can try and address the gaps that have been found in the literature—e.g. address the problem of deciding whether to ignore an existing policy or abort an action in case an unforeseen event takes place and an exception from existing policies is required.

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