Exhibit 24

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Improving Patent Examination Efficiency and Quality:

An Operations Research Analysis of the USPTO, Using Queuing Theory

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Introduction

In recent years, the United States Patent and Trademark Office (USPTO) has proposed a variety of structural reforms to reduce the backlog of pending applications such as: outsourcing patent examiners' search function to commercial vendors,[1] limiting the number of claims examined in each application,[2] and offering the options of deferred examination and accelerated examination.[3] In 2006, the USPTO proposed a limit on the number of Requests for Continued Examination (RCEs) and "continuing" applications

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[1] *United States Patent And Trademark Fee Modernization Act of 2003: Hearing on H.R. 1561 Before the Subcomm. On Cts., the Internet, and Intellectual Prop. of the H. Comm. on the Judiciary*, 108th Cong. 63-66 (2003) (statement of Ronald J. Stern, President, Patent Office Prof'l Ass'n [POPA]), at 63–65, *available at* http://commdocs.house.gov/committees/judiciary/hju86267.000/hju86267_0.htm [hereinafter *Fee Modernization Act Hearing*].

[2] Changes to Practice for the Examination of Claims in Patent Applications, 71 Fed. Reg. 61, 61–62 (proposed Jan. 3, 2006) (to be codified at 37 C.F.R. pt. 1) [hereinafter Proposed Changes to Examination of Claims].

[3] Jay P. Lucas, Deputy Comm'r for Patent Examination Policy, USPTO, How the New [US]PTO Regulations Will Impact Your Practice, Address at George Mason University School of Law: Fifth Annual Symposium on Hot Topics in Patent Law 5, 13-15 (July 18, 2006) (PowerPoint presentation available by request to the author); *see also* Changes to Practice for Petitions in Patent Applications to Make Special and for Accelerated Examination, 71 Fed. Reg. 36323, 36323–24 (proposed June 26, 2006) (to be codified at 37 C.F.R. pt. 1).

(which the USPTO defines as continuations, continuations-in-part, and divisional applications).[4] The inspiration for this reform was an article that argued that continuing applications are an important source of delay.[5] The final version of the reforms was published on Aug. 21, 2007, and will become effective on Nov. 1, 2007.[6] The final version of the reforms is slightly less restrictive than the initially proposed version, but not by much.[7]

The USPTO rationale for limiting continuing applications is that a small number of applications are taking up thirty percent of USPTO patent examining resources.[8] "[A]bout thirty percent . . . of the Office's patent examining resources must be applied to examining continued examination filings that require reworking earlier applications

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[4] Proposed Changes to Practice for Continuing Applications, Requests for Continued Examination Practice, and Applications Containing Patentably Indistinct Claims, 71 Fed. Reg. 48, 48–50 (proposed Jan. 3, 2006) (to be codified at 37 C.F.R. pt. 1) (discussing the USPTO authority to impose limits on RCEs as opposed to limits on continuing applications) [hereinafter Proposed Changes to Continuations].

[5] *See* Proposed Changes to Continuations, *supra* note 4, at 49 (citing Mark Lemley & Kimberly Moore, *Ending Abuse of Patent Continuations*, 84 B.U. L. Rev. 63, 64 (2004)).

[6] Changes To Practice for Continued Examination Filings, Patent Applications Containing Patentably Indistinct Claims, and Examination of Claims in Patent Applications, 72 Fed. Reg. 161 (August 21, 2007) (to be codified at 37 C.F.R. pt. 1).

[7] *Id.* Changes Relative to the Rules Originally Proposed in January of 2006, *available at* http://www.uspto.gov/web/offices/pac/dapp/opla/presentation/ccfrchanges.pdf [hereinafter Changes Relative to the Rules]. The USPTO states that

> The USPTO proposed in January of 2006 to revise continued examination filing practice to permit an applicant to file one (1) of the following continued examination filings without any justification: a continuation application, a continuation-in-part application, or a request for continued examination. In light of the public comment, USPTO modified the proposed changes to continued examination filing practice to increase the number of continued examination filings permitted without justification. Specifically, this final rule adopts a change to continued examination filing practice that permits an applicant to file two continuation applications or continuation-in part applications, plus a single request for continued examination in an application family, without any justification.

Id. *See* Proposed Changes to Continuations, *supra* note 4, at 49 (citing Mark Lemley & Kimberly Moore, *Ending Abuse of Patent Continuations*, 84 B.U. L. Rev. 63, 64 (2004)).

[8] *See* Proposed Changes to Continuations, *supra* note 4, at 50.

instead of examining new applications."[9] At the same time, the USPTO argues that "the Office's proposed requirements for seeking second and subsequent continuations will not have an effect on the vast majority of patent applications."[10] According to the simple calculations presented in the USPTO Notice of Proposed Rulemaking, only about twenty percent of the continuing applications would be affected by this rule.[11]

On its face, the rationale behind this reform does not make sense. How can a reform that *will affect only a small minority of patent applications* produce a substantial improvement in the allocation of USPTO resources? By USPTO calculations, the reform will affect only twenty percent of continuing applications.[12] Since continuing applications take up thirty percent of USPTO patent examining resources, the net result of the initially proposed reform eliminates a mere six percent of pending applications.[13]

There is a logical explanation for the reform – a phenomenon known as *starvation* of priority queues, which will be discussed later in this article.[14] Yet to the authors' knowledge, the USPTO has not discussed this phenomenon, nor have other commentators. Moreover, while the USPTO released a graphical prediction of the impact

[9] *See* Proposed Changes to Continuations, *supra* note 4, at 50.

[10] *See* Proposed Changes to Continuations, *supra* note 4, at 50.

[11] *See* Proposed Changes to Continuations, *supra* note 4, at 50. ("Had there been no continued examination filings, the Office could have issued an action for every new application received in 2005 and reduced the backlog by issuing actions in 35,000 older cases. Instead, the Office's backlog grew because of the large number of continued examination filings.").

[12] *See* Proposed Changes to Continuations, *supra* note 4, at 50.

[13] Continuing applications take up thirty percent of USPTO patent examining resources, and the reform would affect only twenty percent of continuing applications. So, the percentage of applications affected by this reform is the product of thirty percent and twenty percent. In other words, six percent of pending applications.

[14] *See infra* Part II.3.

of the reforms in a USPTO slide presentation,[15] to the authors' knowledge the USPTO has not issued a quantitative study of the expected impact. We also have not found any third-party study that attempts to quantify the impact of these reforms.

What has been lacking is an operations research model. Such a model would describe the existing system quantitatively, and could be adjusted to predict the effects of various functional changes.[16] The purpose of this article is to provide a first step in this direction.

This article creates a model of the current patent system, using concepts taken from a sub-specialty of operations research known as *queuing theory*. Queuing theory itself dates back to 1909.[17] Computer scientists and computer engineers have used queuing theory in the fields of computer hardware and software for at least three decades.[18] Queuing theory is especially useful in the design of computer operating systems.[19] Computer scientists use queuing theory to design computer operating systems

[15] *See* John Doll, Comm'r for Patents, U.S. Patent and Trademark Office, Address at Chicago Town Hall Meeting 50–54 (Feb. 1, 2006), *available at* http://www.uspto.gov/web/offices/pac/dapp/opla/presentation/chicagoslides.ppt.

[16] S. KESHAV, AN ENGINEERING APPROACH TO COMPUTER NETWORKING: ATM NETWORKS, THE INTERNET, AND THE TELEPHONE NETWORK, xiii (Addison-Wesley 1997).

> [T]he engineering approach is to begin by identifying the fundamental constraints on the problem, make reasonable 'real-world' assumptions, and then examine several alternative solutions, trading off their pros and cons. An engineer recognizes that no solution is perfect, but that every solution represents a particular trade-off between cost and benefit.

Id.

[17] *See* UNIV. OF CAMBRIDGE, MILLENNIUM MATHEMATICS PROJECT: AGNER KRARUP ERLANG, 2 (May 1997), http://pass.maths.org.uk/issue2/erlang/2pdf/index.html/op.pdf.

[18] LEONARD KLEINROCK, QUEUING SYSTEMS VOLUME 2: COMPUTER APPLICATIONS, viii, ix (John Wiley & Sons 1975).

[19] *See* ABRAHAM SILBERSCHATZ & PETER BAER GALVIN, OPERATING SYSTEM CONCEPTS 93, 146-47, 149 (5th ed. 1999).

that maximize CPU utilization, maximize throughput, or minimize waiting time.[20] Queuing theory is also widely used is in computer networking, where it is used to analyze and predict network performance.[21]

Queuing analysis has its limitations, however.[22] The most serious limitation is that the authors of a queuing model usually must make a significant number of assumptions, either because of the lack of data, or to simplify the model for the sake of practicality.[23] The resulting model is often only an approximation of the real system; thus, the accuracy of the computed results depends on the skill of those creating the model.[24]

Our model is no exception. In order to apply the limited data that is publicly available about the patent system, we made some major assumptions and simplifications. We have attempted to point out the most important assumptions in the model. We hope that our model will serve as a much needed starting point for further analysis and research.

Part I—The Patent Prosecution Process

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[20] *Id.* at 123–24, 127–28, 144.

[21] *See* KESHAV, *supra* note 16, at 223–24.

[22] SILBERSCHATZ, *supra* note 19, at 147.

[23] *Id.*

[24] *Id.*

The following is a brief summary of the patent prosecution process. In this section we explain the differences between RCEs, continuations, continuations-in-part, and divisional applications.[25]

1. Filing and Classification

When an applicant files a patent application, the USPTO classifies it under the appropriate *art unit* (e.g., chemical, mechanical, electrical).[26] The USPTO classifies the application at least nine weeks prior to publishing it as a pre-grant patent application publication.[27] Publication usually occurs eighteen months after the applicant files the patent.[28] At some later point, the USPTO may reclassify the application.[29] Eventually, the application is placed on the regular new application docket of a specific examiner in an art unit.[30] At some point (depending on the backlog of cases in that art unit), the examiner will begin to examine the application.[31]

The first thing the examiner will look for is whether the application needs to be restricted.[32] In other words, are the claims in the application directed to two or more unrelated inventions? If so, the application needs to be split into two or more

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[25] Readers familiar with this subject matter can skip directly to Part II, which provides a basic introduction to queuing theory.

[26] USPTO, U.S. DEP'T OF COMMERCE, MANUAL OF PATENT EXAMINING PROCEDURE § 903.08 (8th ed. 2006), *available at* http://www.uspto.gov/web/offices/pac/mpep/index.html [hereinafter MPEP].

[27] MPEP, *supra* note 26, § 903.04., § 903.04.

[28] 35 U.S.C. § 122(b) (2006); *see also* MPEP, *supra* note 26, § 1120.

[29] MPEP, *supra* note 26, § 903.08., § 903.08.

[30] MPEP, *supra* note 26, §§ 203.01, 903.08(a)–(b).

[31] MPEP, *supra* note 26, § 903.08.

[32] *See generally* MPEP, *supra* note 26, § 803.

independent applications and the examiner will mail a restriction.[33] This will force the applicant to elect one of the inventions for examination.[34]

2. Restrictions and Divisional Applications

An applicant who receives a restriction has the option of filing one or more divisional applications that contain the non-elected claims.[35] Divisional applications can only disclose and claim subject matter disclosed in the earlier or parent application.[36] No new matter can be added.[37] The default destination for these divisional applications is the examiner's regular new application docket, but since the effective filing date of division applications is the filing date of the original application, applicants often file a Petition to Make Special.[38] Applications with a Petition to Make Special are promoted to the examiner's special new application docket and are given precedence over regular new applications.[39] If the applicant does not respond to the examiner's restriction, the application is abandoned.[40]

3. First Office Action

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[33] *See* MPEP, *supra* note 26, § 803.

[34] *See* MPEP, *supra* note 26, §§ 809.02(a), 818.

[35] MPEP, *supra* note 26, §§ 201.06, 601.01.

[36] MPEP, *supra* note 26, § 201.06.

[37] *See* MPEP, *supra* note 26, § 201.06.

[38] *See* MPEP, *supra* note 26, § 708.02(VIII)(B); *see also* Miku H. Mehta, *Expediting Patent Prosecution By Special Treatment Of Applications*, at 6–7 (2004), http://www.sughrue.com/mmehta (article link in "Publications and Teaching" section).

[39] *See* MPEP, *supra* note 26, § 708.01.

[40]*See* MPEP, *supra* note 26, § 714.03.

If the applicant elects a set of claims, then the examiner proceeds to examine the elected claims.[41] The examination consists of a prior art search and an evaluation of whether the application conforms to other requirements (i.e., an enabling disclosure).[42] When this stage of examination is complete, the examiner must decide whether to issue a notice of allowance in the application or, alternatively, to issue a non-final rejection.[43] If the examiner issues a notice of allowance, and the applicant pays the patent issuance fees, then the USPTO will issue the application as a patent.[44]

4. Applicant's Response to a Non-Final Office Action

If the examiner rejects the application in a non-final office action, the applicant may choose to not respond, thereby abandoning the application.[45] If the applicant chooses to respond in a timely manner, the response must include amendments to the claims, arguments pointing out mistakes in the examiner's rejection, or both.[46]

Such a response is placed on the examiner's regular amended application docket.[47] At this point, the examiner must determine whether there are sufficient grounds for issuing a final rejection.[48] Such rejections are proper when the applicant has not

[41] *See generally* MPEP, *supra* note 26, § 714. If no restriction was necessary, then all of the claims are examined.

[42] *See* MPEP, *supra* note 26, §§ 2100–2190.

[43] *See* MPEP, *supra* note 26, § 706 ("The goal of examination is to clearly articulate any rejection early in the prosecution process so that the applicant has the opportunity to provide evidence of patentability and otherwise reply completely at the earliest opportunity."); s*ee also* MPEP, *supra* note 26, § 1302.02 ("A Notice of Allowability . . . is used whenever an application has been placed in condition for allowance.").

[44] *See generally* MPEP, *supra* note 26, §§ 1302, 1306, 1309.

[45] *See* MPEP, *supra* note 26, § 711.

[46] MPEP, *supra* note 26, § 2266.

[47] *See* MPEP, *supra* note 26, § 1704.

[48] *See* MPEP, *supra* note 26, §§ 706.07(a), 803.01, 1005.

overcome or resolved all of the issues indicated in the non-final rejection, by either amendment or argument.[49] Final rejections are also proper when the applicant responds to the non-final office action by amending the claims in a way that forces the examiner to introduce new grounds for rejection.[50]

If it is not possible to issue a final rejection, the examiner (or his supervisor) must determine whether to allow the application or to mail a new non-final rejection.[51] Theoretically the examiner can issue an infinite number of non-final rejections in an application. In practice, this does not happen because the applicant has a right to an appeal after any two office actions (regardless of whether the second action is final or non-final).[52] In the authors' experience, this right of appeal acts to limit to the number of non-final rejections that examiners issue (even though an examiner can also issue a non-final office action after receiving an appeal brief). An even larger deterrent to repeated non-final actions is the USPTO rule of giving examiners credit (known as *counts*) for only one non-final action in each round of prosecution.[53] The examiner also receives a delayed count for the final office action, which closes that specific round of prosecution.[54]

5. Applicant's Response to a Final Office Action

[49] *See generally* MPEP, *supra* note 26, § 703.

[50] *See* MPEP, *supra* note 26, § 706.07(a)–(b).

[51] *See* MPEP, *supra* note 26, §§ 706.07(a)–(b), 1302.14, 1303.

[52] MPEP, *supra* note 26, § 1204 ("A notice of appeal may be filed after any of the claims has been twice rejected, regardless of whether the claim(s) has/have been finally rejected.").

[53] *See* MPEP, *supra* note 26, § 1705.

[54] *See* MPEP, *supra* note 26, § 706.07.

If the examiner mails a final rejection, the applicant has several options. One option is to abandon the application.[55] Another is to respond with an after-final amendment, which is placed on the examiner's special amended application docket.[56] The examiner may decide to allow the application if the after-final amendment resolves all outstanding issues.[57] If the amendment does not resolve all outstanding issues, or introduces new issues that would require further search or consideration, the examiner may maintain his final rejection and send out an advisory action.[58] An applicant may send as many after-final amendments as he wishes before the statutory deadline.[59]

The applicant may also file a Request for Continued Examination (RCE), instead of abandoning the application or filing an after-final amendment.[60] The filing of an RCE purchases another round of prosecution. Before the effective date of the new reforms, there was no limit on the number of rounds of RCEs that could be filed in an application.[61]

Yet another option available to an applicant who has received a final rejection is to appeal the decision to USPTO Board of Patent Appeals and Interferences (BPAI) by

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[55] *See* MPEP, *supra* note 26, §§ 706.07, 711.

[56] *See* MPEP, *supra* note 26, § 714.12.

[57] *See* MPEP, *supra* note 26, § 1302.14 ("In most cases, the examiner's actions and the applicant's replies make evident the reasons for allowance . . . ."); *see generally* MPEP, *supra* note 26, § 1303.

[58] MPEP, *supra* note 26, § 714.13 (III).

[59] *See* MPEP, *supra* note 26, § 706.07.

[60] MPEP, *supra* note 26, § 706.07(h).

[61] Proposed Changes to Continuations, *supra* note 4, at 51 ("Nothing in 35 U.S.C. 132(b) or its legislative history suggests that the Office must or even should permit an applicant to file an unlimited number of [RCE] in an application.").

submitting an appeal brief.[62] In fact, the applicant can request a pre-appeal conference before submitting an appeal brief.[63] The pre-appeal conference consists of the examiner, the examiner's supervisor, and another USPTO official.[64] The participants decide on one of two options: (1) maintaining the rejections; (2) issuing a notice of allowance (so if the applicant pays the issue fees, then the USPTO will issue the application as a patent); or (3) re-opening prosecution by sending out another non-final rejection.[65]

The applicant can skip the request for a pre-appeal conference and proceed directly to the appeal. Alternatively, the applicant can decide to appeal after receiving a response from the pre-appeal conference that does not include a notice of allowance.[66] Once the applicant files an appeal brief, the USPTO conducts an appeal conference—even if a pre-appeal conference has already been held in the same case.[67] At the conference, which consists of the examiner, his supervisor and another USPTO official, the participants decide on one of three options: (1) writing an Examiner's Answer and sending the application up to the BPAI; (2) allowing the application (so if the applicant pays the issue fees, then the USPTO will issue the application as a patent); or (3) re-opening prosecution by sending out another non-final rejection.[68]

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[62] *See* MPEP, *supra* note 26, § 1201.

[63] See USPTO, Official Gazette Notices, Pre-Appeal Brief Conference Pilot Program (July 12, 2005), http://www.uspto.gov/go/og/2005/week28/patbref.htm. A notice of appeal must be filed before a preappeal conference can be held.

[64] MPEP, *supra* note 26, § 1207.01.

[65] MPEP, *supra* note 26, §§ 1207.01–02.

[66] *See*, USPTO, Official Gazette Notices, *Pre-Appeal Brief Conference Pilot Program* (July 12, 2005), http://www.uspto.gov/go/og/2005/week28/patbref.htm.

[67] MPEP, *supra* note 26, § 1207.01 (making appeal conferences mandatory).

[68] MPEP, *supra* note 26, §§ 1207.01–02.

If the examiner does send the application up to the BPAI, a three judge panel of Administrative Patent Judges decides whether to affirm or reverse the examiner.[69] If they affirm the examiner and there were no allowed claims, the application is abandoned, unless the applicant subsequently files a RCE.[70] If they reverse the examiner, the examiner must allow the application, unless the applicant files an RCE.[71] The BPAI also has the option of adding new grounds of rejection, which enables the applicant to request a re-opening of prosecution.[72] In the authors' experience, this last scenario rarely happens.

6. Continuing Applications

At any point after the filing of the application (but prior to abandoning or issuing the application), the applicant can file a continuing application—an application that repeats a substantial portion, or all, of an earlier application.[73] This continuing application is distinct from the original application and is docketed and examined independently from the original application.[74] There are three types of continuing applications (spelled with an -ing): divisional applications, continuation applications (spelled with a -tion), and continuation-in-part applications.[75] In the authors' experience,

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[69] *See* MPEP, *supra* note 26, §§ 1213, 1214.04, 1214.06.

[70] MPEP, *supra* note 26, § 1214.07.

[71] MPEP, *supra* note 26, § 1214.07.

[72] MPEP, *supra* note 26, § 1213.

[73] *See* 37 C.F.R. § 1.53 (2006).

[74] *Id.*

[75] *See* Proposed Changes to Continuations, *supra* note 4, at 50.

the USPTO places all three types of continuing applications on an examiner's *special new application* docket.

If the applicant adds new matter to the specification in a continuing application, it is called a "continuation-in-part."[76] If an examiner's restriction of the originally filed claims necessitated the continuation application, it is called a divisional application.[77]

If the continuing application contains no new matter, was not necessitated by an examiner's restriction requirement, and adds new claims directed to the same invention as in the parent application, the continuing application is called a continuation.[78]

Prior to the new reforms, the applicant was allowed to file an unlimited number of continuing applications.[79] The applicant also was allowed to file an unlimited number of second and later generations of continuing applications.[80] "[T]he current unrestricted continuing application and request for continued examination practices preclude the

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> 35 U.S.C. 111(a) and 120, respectively, permit an applicant to file a nonprovisional application and to claim the benefit of a prior-filed nonprovisional application. Similarly, 35 U.S.C. 363 and 365(c), respectively, permit an applicant to file an international application under Patent Cooperation Treaty (PCT) Article 11 and 35 U.S.C. 363 and, if the international application designates the United States of America, claim the benefit of a prior-filed international application designating the United States of America or a prior-filed nonprovisional application. Similarly again, 35 U.S.C. 111(a) and 365(c) permit an applicant to file a nonprovisional application (filed under 35 U.S.C. 111(a)) and claim the benefit of a prior-filed international application designating the United States of America (under 35 U.S.C. 365(c)).

Id.

[76] MPEP, *supra* note 26, § 201.08.

[77] 35 U.S.C. § 121 (2000).

[78] *See generally* Proposed Changes to Continuations, *supra* note 4, at 50.

[79] MPEP, *supra* note 26, § 201.07; Proposed Changes to Continuations, *supra* note 4, at 50 ("The Office is aware of case law which suggests that the Office has no authority to place an absolute limit on the number of copending continuing applications originating from an original application."). For example, U.S. Patent No. 6,988,026 is a particularly egregious example of unrestrained continuation practice, having no less than 11 continuations-in-part. U.S. Patent No. 6,988,026 (filed Nov. 4, 2003).

[80] MPEP, *supra* note 26, § 201.07.

[USPTO] from ever finally rejecting an application or even from ever finally allowing an application" because there was no limit to the number of continuing applications or RCEs a party was allowed to file, except in the rare situation of prosecution laches.[81]

Part II—Basic Queuing Theory Concepts

1. The Server

We now change gears to provide a basic introduction to concepts in queuing theory.[82] Our introduction begins with Figure 1, which shows an abstract server and its queue.[83] The role of the server is to process (or *serve,* hence the term *server*) arriving items.[84] If there is no queue, the server immediately processes arriving items. If a queue of arrived items has already formed, the newly arriving items wait at the end of the queue.[85] Only when an item is at the front of the queue does the server process it.[86] When the processing is complete, the processed item departs from the server.[87]

[81] Proposed Changes to Continuations, *supra* note 4, at 49–50, 52; *see also* In re Bogese*,* 303 F.3d 1362, 1369 (Fed. Cir. 2002) (holding that the USPTO has the authority to order forfeiture of rights if a party persists in unreasonable delay).

[82] This material serves as background for our queuing theory model of the USPTO. Readers familiar with this material can skip to Part III, where we apply this material to the USPTO.

[83] EDWARD D. LAZOWSKA, ET AL., QUANTITATIVE SYSTEM PERFORMANCE 4-5 (Prentice-Hall 1984), *available at* http://www.cs.washington.edu/homes/lazowska/qsp/.

[84] *See id.* at 4. These terms have many synonyms. Items can be called customers, tasks, or "processes." *Id.* Servers can be called processors, processes servers, or service units. *Id.*

[85] *Id.* at 4–5.

[86] *Id.* at 4–5.

[87] *Id.*

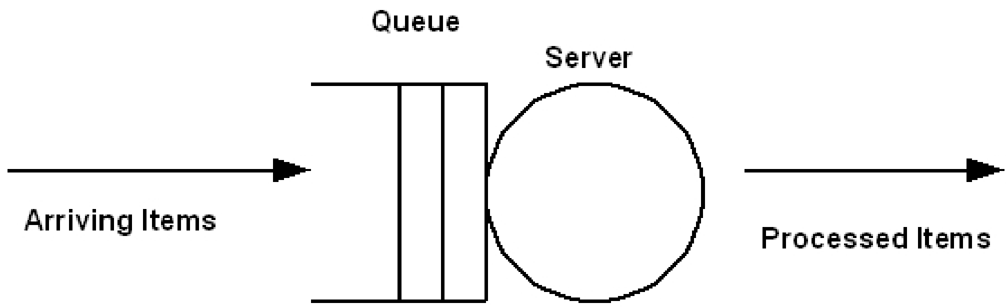

Figure 1—Server and Queue.

Most queuing models have two critical parameters: mean *incoming* rate, and mean *service* rate.[88] The mean incoming rate is the average rate at which items arrive, measured in items/hour, or some similar metric.[89] The mean service rate is the rate at which the server processes incoming items.[90]

These two factors directly influence the queue length.[91] When the mean arrival rate is greater than the mean service rate, the queue length grows over time.[92] The traffic intensity variable (the ratio of the mean incoming rate divided by the mean service rate) represents this relationship.[93] When the traffic intensity is greater than or equal to one,

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[88] *Id.* at 5 (referring to *mean arrival rate* as *workload intensity*, and to *mean service rate* as *throughput*). This article will symbolize mean arrival rate as λ and mean service rate as μ. *See infra* Appendix I.

[89] LAZOWSKA, *supra* note 83, at 5.

[90] *Id.* The characteristics of λ and μ are discussed in greater detail in Part IV, § 3 of this paper.

[91] *See infra* Appendix I (defining the symbol for queue length as L, which is a function of λ and μ).

[92] *See infra* Appendix I (defining key relationships which are affected by assumptions regarding the relationship between λ and μ). The proposition that mean arrival time is greater than mean service rate is represented mathematically as $\lambda \geq \mu$.

[93] *See infra* Appendix I (defining key relationships which are affected by assumptions regarding the relationship between ρ, λ, and μ). The ratio of the mean incoming rate divide by the mean service rate is represented mathematically as $\rho = \lambda / \mu$.

new items arrive at a rate faster than the server can process them.[94] The resulting queue grows continuously, as does the waiting time for items arriving to the queue. The system becomes saturated.

On the other hand, if the traffic intensity is less than one, then we can calculate the mean queue length.[95] When the traffic intensity is less than one, we can use Little's Law to calculate the relationship between mean queue length and mean waiting time.[96]

2. Feedback and Branching Feedback

A *simple queue* refers to a single queue of items arriving at a service processor, as discussed in the previous section (and shown in Figure 1). Simple queues can have additional interesting features, such as *feedback* and *branching feedback*.

Feedback refers to serviced items that immediately return to the arrival queue—rather than departing permanently.[97] Feedback increases queuing length and queuing time because it increases the number of arriving items. Feedback increases the workload intensity. Figure 2 shows an example of feedback.

Branching feedback occurs when one departing item multiplies into at least two arriving items,[98] thereby increasing queuing length and time even more than regular feedback. Figure 3 shows an example of branching feedback.

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[94] *See infra* Appendix I (defining key relationships which are affected by assumptions regarding the relationship between ρ, λ, and μ). This is represented mathematically as $\rho \geq 1$ or $\lambda \geq \mu$.

[95] *See infra* Appendix I (defining the formula for L, which converges to a single number if $\rho<1$).

[96] Little's Law is $L = \lambda W$, where (W) is the waiting time. WAYNE L. WINSTON, OPERATIONS RESEARCH: APPLICATIONS AND ALGORITHMS 1074–76 (4th ed. 2004); *see also* LAZOWSKA, *supra* note 83, at 42–44 (discussing Little's Law).

[97] B. Simon, *Priority Queues with Feedback*, 31 J.A.C.M. 134, 135–36 (1984).

[98] *Id.* at 144.

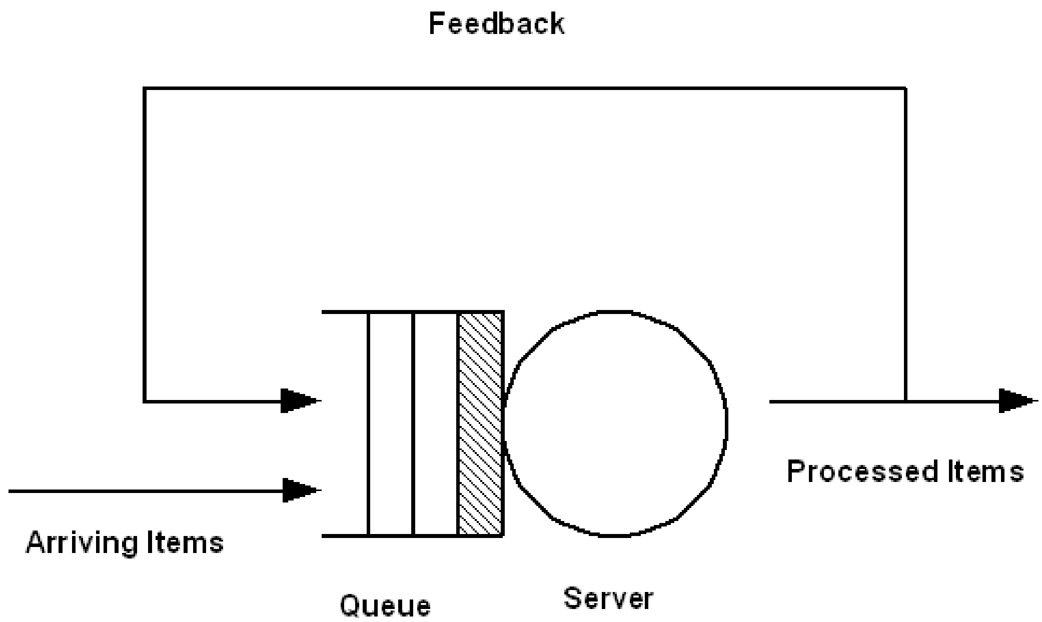

Figure 2—Queue with Feedback

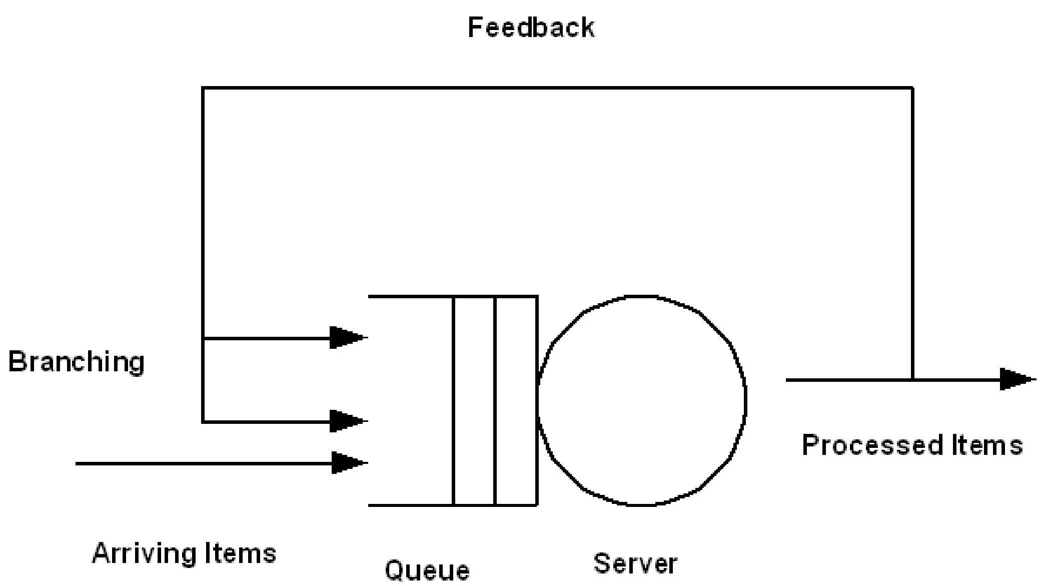

Figure 3—Queue with Branching Feedback

3. Priority Queues

A *priority queue* differs from a *simple queue* by having multiple queues per server, instead of just one.[99] In a priority queue, each queue is associated with a *priority level*.[100] The server initially processes items in the highest priority level.[101] If there are no items in the highest priority level, the server will process an item from the next lower priority level, and so on down to the lowest level.[102] Figure 4 shows an example priority queue.

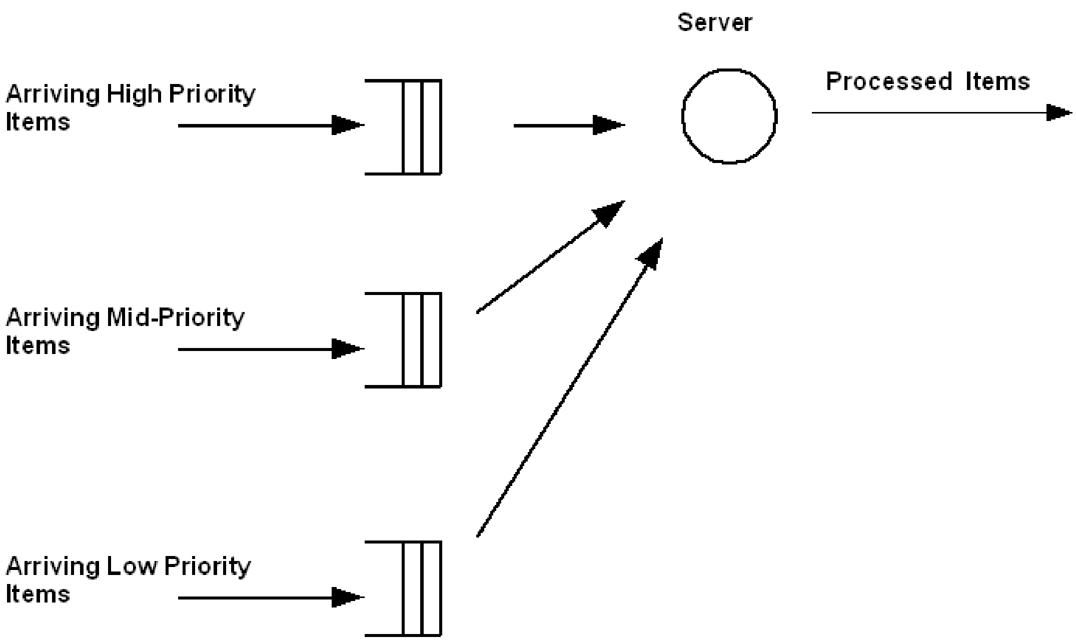

Figure 4—Priority Queue

Priority queues have several interesting characteristics. First, higher-priority arrivals have a short queuing delay, but this is at the expense of long queuing delays for

[99] KESHAV, *supra* note 16, at 223; *see also* SILBERSCHATZ, *supra* note 19, at 133.

[100] KESHAV, *supra* note 16, at 223.

[101] KESHAV, *supra* note 16, at 223.

[102] KESHAV, *supra* note 16, at 223.

lower-priority arrivals.[103] Second, if there is a sufficiently high rate of new arrivals in the higher priority queues, the server will never serve lower-priority arrivals.[104] This phenomenon is known as *starvation*.[105] Therefore, in order to ensure that the server will process items in the lowest priority queue, servers are often designed with so-called *admission control policies* that limit the arrival rates at all priority levels other than the lowest priority level.[106]

As with simple queues, priority queues can also have regular feedback and branching feedback. An aspect unique to priority queues is that feedback items can arrive at a higher or lower priority level than the initial arrivals. Figure 5 shows a sample priority queue with one form of branching feedback.

[103] KESHAV, *supra* note 16, at 223 (discussing priority queues in computer networking context). "Priority allows a scheduler to give packets at a higher priority level a lower mean queuing delay at the expense of packets at lower priority levels."

[104] KESHAV, *supra* note 16, at 223 ("An extreme case of this is *starvation*, where the scheduler never serves a packet at a lower priority level, because there is always something to send from a higher priority level."); *see also* SILBERSCHATZ, *supra* note 19, at 170–71.

[105] KESHAV, *supra* note 16, at 223.

[106] KESHAV, *supra* note 16, at 223 ("Thus, in a priority scheduler, it is critical that appropriate admission control and policing restrict the service rates from all but the lowest priority level."); *see also* Michael J. Carey et al., *PRIORITY IN DBMS RESOURCE SCHEDULING*, Proceedings of the 15th Int'l Conf. on Very Large Data Bases 397 (Aug. 22–25, 1989) (discussing the importance of priority scheduling in operating systems), *available at* http://www.vldb.org/conf/1989/P397.PDF.

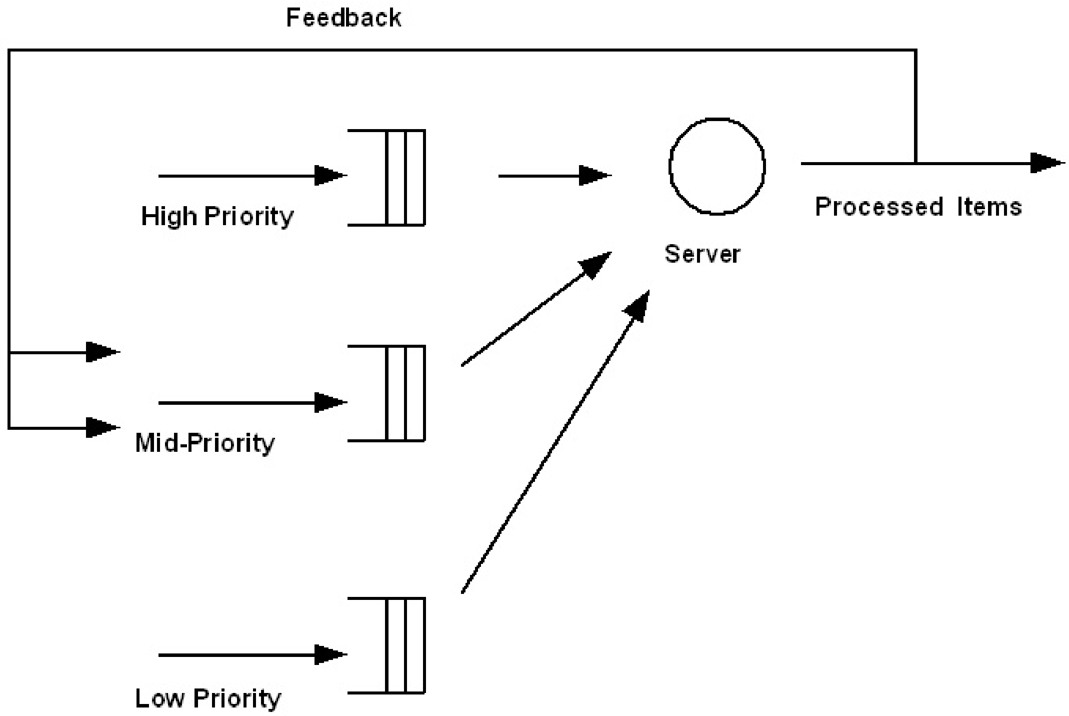

Figure 5—Priority Queue with Branching Feedback

Part III—Queuing Structures in the USPTO

1. The USPTO as a Server

Our first major design choice when constructing our queuing theory model of the USPTO was whether to represent the USPTO as a single server, or as a group of multiple servers. For the sake of simplicity, we chose to represent the USPTO as a single server, even though in reality the USPTO consists of many independent servers with varying characteristics. There are large variances in the application arrival rates, service rates, queue lengths, and numbers of examiners in the USPTO different technology centers, and their lower echelons, known as *art units*.[107]

For example, average application pendency, from the filing date of the application until the mailing date of the first office action varies from as many as fifty-two months in the Finance and Banking art, to as few as nine months in the Electrical Connector art.[108] The backlog of unexamined cases also varies by art unit, with the range varying from eight to 130 months worth of new applications.[109] In our model, we simplify this complexity by aggregating all of these units into one big server, and focusing on USPTO-wide statistics. These results therefore are averages for the entire USPTO, so applicants in specific arts may see results that vary widely from the average.

There are also large variances at the individual examiner level. The amount of time the USPTO allocates to examiners for examining an application depends on the examiner's seniority and art unit.[110] The USPTO allocates fewer hours per application to senior examiners and fewer hours per application to examiners in simpler arts.[111]

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[107] *See* Doll, *supra* note 15, at 12–14, 20.

[108] *Id.* at 12.

[109] *Id.* at 13.

[110] OFFICE OF INSPECTOR GEN., U.S. DEP'T OF COMMERCE, FINAL INSPECTION REPORT NO. IPE-15722/SEPTEMBER 2004, USPTO SHOULD REASSESS HOW EXAMINER GOALS, PERFORMANCE APPRAISAL PLANS, AND THE AWARD SYSTEM STIMULATE AND REWARD EXAMINER PRODUCTION, 7 & n.6 (2004), *available at* http://www.oig.doc.gov/oig/reports/2004/USPTO-IPE-15722-09-04.pdf [hereinafter OIG REPORT]. *See also* John R. Allison, Mark A. Lemley, Kimberly A. Moore & R. Derek Trunkey, *Valuable Patents*, 92 GEO. L.J. 435, 464 n.127 (2004).

[111] *Review of U.S. Patent and Trademark Operations, Including Analysis of General Accountability Office, Inspector General and National Academy of Public Administration Reports: Before the Subcomm. on Courts, the Internet and Intellectual Property of the H. Comm. on the Judiciary*, 109th Cong. 4 (Sept. 8, 2005) (statement of Ronald J. Stern, President, Patent Office Professional Association), *available at* http://judiciary.house.gov/media/pdfs/stern090805.pdf ("Primary examiners, those at GS grades 14 and 15 with authority to act independently, are expected to be much more productive than junior examiners requiring various levels of supervision."). *See also* OIG REPORT, *supra* note 110, at 7 ("[US]PTO has

In our model, we chose to apply the statistics for the average examiner to all examiners. Since the average examiner at the USPTO in 2003 was at the GS-12 pay grade, we applied the examining time per application statistic for the GS-12 pay grade (10.25 hours per office action) to all of the examiners in the entire USPTO.[112]

2. Feedback and Branching Feedback at the USPTO

Any model of the USPTO must include feedback, since most applications that the USPTO processes return to the USPTO arrival queue during prosecution. Every applicant response is a form of feedback, regardless if it is a response to a restriction, a response to a non-final office action (i.e., amendments, requests for reconsideration), or a response to a final office action (i.e., after-final amendments, requests for pre-appeal conferences, appeal briefs, and RCEs).

Moreover, due to the existence of continuing applications (continuation applications, continuation-in-part applications, divisional applications), any model of the USPTO must also include branching feedback. Continuing applications are new applications that claim benefit of an original application still alive in the system at the time of the continuing application's filing.[113] These continuing applications constitute "branching" feedback because one departing item multiplies into at least two arriving

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hundreds of expectancy goals — the average number of hours within which examiners must process each application — based on different technologies.").

[112] *See also* OIG REPORT, *supra* note 110, at 7 ("Based on all art unit technologies, the fiscal year 2003 GS-12 equivalent hours for two counts was 20.5."). This corresponds to 10.25 hours per office action. *See also id*. at 33 (providing the numbers of examiners at different GS levels between the years 1998 and 2003). We derived the average (mean) examiner level of GS-12 for 2003 based on these statistics. For the entire time span between 1998 and 2003, the average GS level was a little lower – around 11.80. *But see* Mark Lemley, et al. *What to Do About Bad Patents?,* REG., Winter 2005-2006, at 10 [hereinafter *Bad Patents*] (citing an average of 18 hours per application) *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=869826.

[113] MPEP, *supra* note 26, § 201.07, at 200-53.

items. As discussed earlier, a non-trivial percentage of the USPTO workload consists of "continuing applications" (continuations, continuation-in-part, divisional applications).[114]

3. Priority Queues at the USPTO

Based on the discussion above, the most accurate model of the current patent system is a priority queue with both feedback and branching.[115] In addition, a priority queue is necessary in a model of the USPTO, because USPTO policy requires patent examiners to examine applications in a specific order of priority, based on their prosecution status.[116]

Currently, the USPTO arranges patent examiners' dockets into four separate queues.[117] The four dockets, listed in order from lowest priority to highest, are regular new applications, special new applications, regular amended applications, and special amended applications.

At the lowest level of priority are regular new applications.[118] Special new applications are the next highest in priority.[119] Examiners are supposed to examine special new applications out of turn—in other words, before examining regular new applications.[120]

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[114] Proposed Changes to Continuations, *supra* note 4, at 50. *See also* Doll, *supra* note 15, at 18.

[115] Simon, *supra* note 97, at 134, 144–45.

[116] *See* MPEP, *supra* note 26, § 708, at 700-132–33.

[117] *See* MPEP, *supra* note 26, §§ 708, 1704(I), at 1700-6.

[118] MPEP, *supra* note 26, § 708, at 700-132. *See also* 37 C.F.R. § 1.102 (2007).

[119] *See* MPEP, *supra* note 26, §§ 708, 708.01, at 700-132–33.

[120] *See* MPEP, *supra* note 26, § 708.01, 700-133.

Within both the special new and the regular new queues, the USPTO generally sorts the applications according to the oldest effective filing dates.[121] The only exceptions are continuation-in-part applications, which the USPTO dockets according to the actual filing date.[122] Examiners may examine continuation-in-part applications based on either their effective or actual filing date.[123]

Unlike the situation with regular and special new applications,[124] examiners are given deadlines for examining amended applications. Applications in the regular amended queue, for example, require an examiner response within two months.[125] Applications in the special amended queue are at the highest priority because examiners must reply to them within ten days.[126] Therefore, regular amended applications are at a higher priority than special new applications.

Special amended applications, with their short deadlines, have the highest priority.[127] These applications are either after-final amendments or decisions from the BPAI, and therefore are cases at the tail end of prosecution. The special amended and regular amended queues are sorted according to the filing date of the last paper filed in the application, due to the deadlines for an examiner response.[128]

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[121] OIG REPORT, *supra* note 110, at 5, 27-28. *See also* MPEP, *supra* note 26, §§ 706.02(V), 708.

[122] MPEP, *supra* note 26, § 708, 700-133.

[123] *Id.* at 700-133.

[124] *See id.* at 700-132–133.

[125] MPEP, *supra* note 26, § 203.08(II), 200-106.

[126] MPEP, *supra* note 26, § 714.13(III), 700-260. *But see* MPEP, *supra* note 26, § 2265(I), 2200-105 (stating a five day deadline).

[127] *See* MPEP, *supra* note 26, § 708, at 77-132.

[128] *See* MPEP, *supra* note 26, § 203.08(II), at 200-106.

Part IV—The Model and the Results

1. Assumptions

When we designed this model, we made a wide variety of assumptions for the purpose of simplification. We assumed a constant rate of applications and a constant number of examiners in order to preserve an underlying steady state. Otherwise, with a dynamically changing application rate, and with unsteady hiring patterns, the model would be much more complex. While in reality the USPTO is hiring hundreds of new examiners every year and the number of applications filed is rising every year, we justify our simplifications by equalizing the rate of USPTO hiring and the rate of application growth. We hold both are constant over time.

We assumed that the proposed reforms were bright-line limits on the numbers of RCEs and continuations. We ignored the processing burden imposed on the USPTO by having to review the petitions for second and subsequent RCEs and continuations.

We also ignored procedural options that currently place a burden on the USPTO. For example, applicants can appeal after any two rejections.[129] We ignored this and assumed that applicants only appeal after a final rejection. We ignored design and plant patent applications. We did not factor remands from the BPAI into the model, nor re-examinations, re-issues, requests for suspension, petitions, or PCTs

2. Our Model

The details of the model (equations and input data), as well as the sensitivity analysis, are available in the appendices to this article. We provide a conceptual summary here.

[129] 37 C.F.R. § 41.31(a)(1) (2007).

Our model is a priority queue with branching feedback. Therefore, it is important to estimate the arrival rate for each *class* of application (regular new, RCEs, continuing applications, etc.). We calculate these values in Part 1 of Appendix III, based on publicly available input data.

After we estimated the arrival rate for each *class* of application, we independently calculated the arrival rate and service rate for each *priority queuing level*. Since each priority queue receives different types of applications, their arrival rates will differ. We calculated these in Part 2 of Appendix III. Based on our personal experiences, we set the service rates to be constant for all priority levels except special amended. This is because special amended cases (e.g. after-final amendments) are usually disposed of more quickly than applications in other priority levels.

3. Our Predictions Before Conducting the Simulation

Before conducting the simulation, we assumed that the queuing theory concepts of priority queues and branching feedback would demonstrate the efficacy of limiting the number of RCEs and continuing applications for the following reasons:

(1) A priority queue processes higher priority items first, giving them a shorter queuing delay – but at only at the expense of longer queuing delays for lower-priority arrivals.[130] Large numbers of high priority arrivals result in disproportionately long waiting times for lower priority arrivals.[131] Since the USPTO gives higher priority to

[130] KESHAV, *supra* note 16, at 223. *See also* SILBERSCHATZ, *supra* note 19, at 133-35, 138-40.

[131] KESHAV, *supra* note 16, at 223.

RCEs and continuing applications than to regular new applications, large numbers of RCEs and continuing applications should result in disproportionate waiting times for regular new applications.[132]

(2) At the very least, a limit on the number of continuing applications would be desirable because continuing applications can produce multiple generations of unlimited numbers of high priority offspring.[133] RCEs and multiple non-final office actions both contribute to the risk of starvation, but pose less potential risk than continuing applications because they do not produce parallel offspring (branching feedback).

4. Simulation Results for Pre-Reform Status Quo

We ran our estimated parameters and derived formulas in the MATLAB software program.[134] According to the results, the pre-reform status quo traffic intensity (ρ) for the four priority levels are $\rho_1 = 0.0044$ for the special amended priority level, $\rho_2 = 0.8262$ for the regular amended priority level, $\rho_3 = 0.0799$ for the special new priority level, and $\rho_4 = 0.3124$ for the regular new priority level. These numbers indicate that the traffic intensity is very high for regular amended applications – much higher than any other priority level. The traffic intensity at the regular amended level is over two-and-a-half times greater than at the regular new level.

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[132] *See id.*

[133] MPEP, *supra* note 26, § 201.07, at 200-53. *See also* Proposed Changes to Continuations, *supra* note 4, at 50. (citing *In re Hogan*, 559 F.2d 595, 603–05 (C.C.P.A. 1977) and *In re Henriksen*, 399 F.2d 253, 262 (C.C.P.A. 1968)) ("The Office is aware of case law which suggests that the Office has no authority to place an absolute limit on the number of copending continuing applications originating from an original application.").

[134] The parameters and formulas are presented in the appendices.

The total traffic intensity for the USPTO is the sum of the traffic intensities of all four priority levels. The sum is ρ = 1.2230, which is greater than one by a large margin. This means that the USPTO model is saturated and is overwhelmed. Some sort of policy change is needed to lower the total traffic intensity.

5. Simulation Results for Limiting the Rounds of RCEs

If we were to allow applicants to file only one RCE per application, as mandated by the final version of the reforms,[135] the result is that ρ_2 = 0.7911 and ρ_3 = 0.0781, resulting in a total intensity of ρ = 1.1860. This is not much of an improvement over the current situation. If we allow RCEs to be filed at most twice, then ρ_2 = 0.8196 and ρ_3 = 0.0796, while ρ_1 and ρ_4 remain the same, and the total intensity is ρ = 1.2160. This is not much of an improvement over the current situation, where the total intensity is ρ = 1.2230. The total intensity is still larger than one by a large margin.

In fact, if we were to eliminate RCEs completely, the result would be ρ_2 = 0.6423, and ρ_3 = 0.0703, so the resulting total traffic intensity would be ρ = 1.0291. This traffic intensity would still be greater than one (albeit marginally) and, therefore, the system would still be saturated.

From these results, we can see that second and later rounds of RCE do not currently add much traffic intensity to the system. Perhaps in the future they will, but it is not currently a pressing problem. Eliminating the second or later rounds of RCEs will not improve the current situation. The first round of RCE contributes somewhat to the traffic intensity, but it seems unfair to eliminate RCEs completely.

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[135] Changes Relative to the Rules, *supra* note 7 ("Specifically, this final rule adopts a change to continued examination filing practice that permits an applicant to file two continuation applications or continuation-in part applications, plus a single request for continued examination in an application family, without any justification.").

6. Simulation Results for Limiting the Number of Generations of Continuing Applications

If we prohibit second and later generation of continuing applications, we have $\rho_1 = 0.0043$, $\rho_2 = 0.7936$, $\rho_3 = 0.0645$, $\rho_4 = 0.3124$, and the total traffic intensity is $\rho = 1.1747$. As with the proposed RCE reform, this is not much of a change from the current situation. If we were to eliminate all continuing applications, then $\rho_1 = 0.0038$, $\rho_2 = 0.7020$, $\rho_3 = 0.0209$, $\rho_4 = 0.3124$, and total intensity is $\rho = 1.0390$. Again, this value is above one and indicates a saturated system.

Therefore, based on the current statistics, the results from limiting continuing applications seem similar to the results from limiting RCE applications. Prohibiting second and later generations of continuation application, as the only policy change, will not have much impact.[136] It may help somewhat to prohibit all continuations, but the system will remain saturated, and as with eliminating RCEs, it is unfair to the applicants.

This is not to say that the USPTO does not need safeguards to prevent an excessive use of continuation applications from becoming a workload problem in the future. A policy limiting continuation applications would be similar to the "admission control policies" used to limit the number of arriving items in computer operating system priority queues.[137] What this analysis shows, however, is that based on *current* statistics, such a policy will not *currently* have much of an effect.

7. Simulation Results for Reducing the Number of Non-Final Rejections Per Round of Prosecution

[136] It could also be contrary to the law. *See* 35 U.S.C. §§ 120, 132(b) (2007).

[137] KESHAV, *supra* note 16, at 223 ("Thus, in a priority scheduler, it is critical that appropriate admission control and policing restrict the service rates from all but the lowest priority level.").

We have no data on the probability of issuance or rejection, but we roughly estimate it in the following way. Assume that for the first round of prosecution, the probability to reach the final rejection is $p_f^{(1)} = 0.4841$, and on average, there are 2.6 decisions, in which 1.6 is non-final.[138] If we neglect the possibility of abandonment after the non-final rejections, the probability of rejection for each decision is roughly $0.4841^{1/2.6} = 0.7565$.

If we limit the number of non-final rejection to one (that means two decisions in each round – one final and one non-final), then n_p is changed to one, and $p_f^{(1)}$ will increase to $0.7565^2 = 0.5723$. The new traffic intensity as follows: $\rho_1 = 0.0053$, $\rho_2 = 0.5783$, $\rho_3 = 0.0818$, $\rho_4 = 0.3124$, and total intensity is $\rho = 0.9777$. This value is less than one, which means that the system is not saturated.

Therefore, we find that the excessive number of non-final rejections per application is the main cause of the system's saturation. The sensitivity analysis performed in Appendix IV supports this conclusion. This number of excessive non-final rejections in each round of prosecution dwarfs the number of second and later RCEs and continuation applications. Reducing the number of non-final rejections per application is the most effective way to improve the throughput of the USPTO. This will help reduce the primary burden on the system — the large number of regular amended cases that remain alive in the system due to repeated non-final rejections.

8. Simulation Results for Increasing the Number of Examiners

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[138] *See* Iowa State University Research Foundation, Inc. Office of Intellectual Property & Technology Transfer, Patents and the Patent Process 7 (Feb. 3, 2007) ("*How many office actions will occur?* It is reasonable to expect to receive three office actions per application. If continuations are filed, for example, there will be additional office actions issued.") http://www.techtransfer.iastate.edu/en/for_iowa_state/educational_resources/patents_and_the_patenting_process.cfm. *See also* OIG REPORT, *supra* note 110, at 17 (reporting 2.4 actions per application in 2002).

On the surface, increasing the number of examiners appears be the most straightforward way to fix the system. If we increase the number of examiners by a certain factor r, then the average incoming rate for each examiner will decrease by $1/r$, and the intensity of each priority level and hence the total workload will decrease proportionally.

That is to say, if we keep the current policies on RCE, continuations, and non-final rejections, we would need to increase the number of examiners by a factor of 1.2230 in order to decrease the total intensity from 1.2230 to 1. This would mean hiring 4215 x 0.2230 = 940 new examiners.[139] (The USPTO goal for fiscal years 2005 and 2006 was to do exactly that.)[140]

Hiring additional examiners is a problematic solution. Our hiring calculations are based on a on a "steady state" assumption that the growth rate of applications will remain proportional to the growth rate of the examining corps. However, for many years the incoming rate of applications has been rising, and is expected to continue to rise in the future. This means that the number of patent examiners would need to grow *at least* at a rate proportional to growth rate of new applications, *ad infinitum*. An exponential growth in hiring is not a sustainable solution. The USPTO has recognized that hiring is not a viable long-term solution to the problem.[141] We propose the following reforms as an alternative to hiring examiners and as an alternative to the recently implemented reforms.

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[139] *See* Doll, *supra* note 15, at 20.

[140] *Id.*

[141] *See id.* at 33.

Part V—Our Proposed Reforms

All of the following reforms are designed to increase the efficiency of the examination process by: (1) automating tasks which are performed faster by machine; and (2) reducing human error, thereby reducing the mistakes that lead to multiple non-final office actions per round of prosecution.

Unlike one previous USPTO proposal which sought to increase throughput (the service rate) by outsourcing patent examiners' search function to commercial vendors,[142] our proposals focus on reforms that increase both quality and save time. By doing both, we increase throughput.

1. Automate Double Patenting Rejections

The USPTO can automate some examination tasks that examiners currently conduct manually. Automation can reduce the number of errors, and consequently should lower the average number of non-final office actions per application. Certain examination tasks are amenable to automation.

Double patenting searches and rejections are particularly amenable to automation, yet currently examiners conduct them manually. There are two types of double patenting rejections.[143] One type is the "same invention" statutory double patenting rejection based on 35 U.S.C. § 101 (2006), which prevents an applicant from obtaining more than one patent for a given set of claims.[144] Statutory double patenting should be easy to detect using computer software because the claim language in the application must be identical to the language in another application or patent.

[142] *Fee Modernization Act Hearing*, *supra* note 1, at 63.

[143] MPEP, *supra* note 26, § 804, at 800-11.

[144] MPEP, *supra* note 26, § 804, at 800-11.

The second type of double patenting rejection is the "obviousness-type."[145] This type is based on a judicially created doctrine designed to prevent the prolongation of issued patent terms by prohibiting the patenting of claims that are "patentably indistinguishable" from issued patents.[146] This type of double patenting should also be easy to detect using computer software, since the claim language in the application must be very similar to the language in another application or patent.

Currently, examiners perform double patenting searches on all new applications. Although examiners and quality assurance specialists at the USPTO catch many double patenting issues, some double patenting issues slip through the patent office undetected, often resulting in litigation.[147] According to some QA reports, 15% - 20% of allowed applications contain double patenting issues that the examiner did not detect.[148]

We do not have the tools to determine how much it would cost to build a computer system that would automatically check for double patenting. We can estimate, on the other hand, that such a system would reduce the number of improperly allowed patents. It would reduce the amount of time examiners spend searching for possible double patenting issues for each and every application. It would also reduce examiners' need to send out supplemental non-final office actions due to previous oversight.

2. Automate Prior Art Searches

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[145] MPEP, *supra* note 26, § 804, at 800-11.

[146] *Id.* at 800-11–12. Non-statutory double patenting includes rejections based on either a one-way determination of obviousness or a two-way determination of obviousness. *Id.* Only rarely is a non-statutory double patenting rejection not the usual "obviousness-type" double patenting rejection. *Id.* This rare type of double patenting rejection is limited to the particular facts of In re Schneller, 397 F.2d 350 (C.C.P.A. 1968). *Id.*

[147] *See generally* MPEP, *supra* note 26, § 1504.06, at 1500-50.

[148] *See generally* MPEP, *supra* note 26, § 1504.06, at 1500-50.

Prior art searches can also be automated. In particular, inventors often neglect to disclose relevant published articles, pre-grant patent publications, and issued patents that they have authored.

Examiners currently search for these references manually. An automated inventor name search would find such documents more quickly, and more accurately. Ideally, an automated search would also include relevant references in the file wrapper before the examiner picked up the case for examination. As with automated double-patenting searches, automating inventor name searches would reduce the number of improperly allowed patents. It would reduce the amount of time examiners spend searching for undisclosed inventor-authored art in each and every application. It would also reduce examiners' need to send out supplemental non-final office actions due to previous oversight.

Another way of automating the prior art search is to use expert system software to perform searches based on key words in the application claims and specification. It is possible that such an automated process would lead some applicants to try to disguise their invention with creative use of synonyms. However, this is already a widespread practice. Moreover, an examiner would always review the search results and apply 35 U.S.C. §§ 101 and 112 (2006) rejections where appropriate for claims that are too vague or methods that produce no relevant results.[149]

3. Reducing Examiners' Form Paperwork

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[149] Again, there are open questions about cost effectiveness, which are beyond the scope of this study.

The USPTO requires examiners to fill out paperwork created when all patent prosecution was conducted in paper files. These manually filled-out forms are time consuming, prone to error, and an inefficient way to perform the intended task.

Over the past few years, the USPTO has transitioned from paper files to the "Image File Wrapper" (IFW) storing patent applications as computer files. All pending applications now are stored electronically, and increasingly applicants are filing their applications electronically. Yet examiners are still required to manually complete forms identical to the forms that originally were designed to be printed on the outside of the old paper wrappers. The USPTO should automate the acquisition, storage, and retrieval of the information recorded in these forms. This would save time, reduce error, and by reducing error, would reduce need to send out supplemental non-final office actions due to previous oversight.

One relevant example is the "Index of Claims" form.[150] This form is intended to be a "reliable index of all claims standing in an application, and of the amendment in which the claims are to be found."[151] The original version, which was printed on the outside of paper file wrappers, was well adapted to its purpose. Now that applications are stored electronically, and increasingly are filed electronically, the USPTO should automate the acquisition and storage of the relevant information. The current system (checking boxes in a Microsoft Word document which is then scanned into the IFW of the application) is neither an efficient use of the examiner's time, nor is it an effective way of tracking the prosecution history of the claims in an application.

[150] MPEP, *supra* note 26, §§ 707.07(i), 719.04, at 700-129, 700-304.

[151] MPEP, *supra* note 26, § 719.04, at 700-304.

Another relevant example is the "Issue Classification" form.[152] This form is filled out for all patent applicants that will be issued as patents.[153] As with the "Index of Claims" form, it was well adapted to its original purpose when it was printed on the outside of paper file wrappers. Now that applications are filed, searched, and stored electronically, there are more time-efficient ways of obtaining and storing this information. As with the "Search Notes" form,[154] the "Issue Classification" form has a section dedicated to patent classes and sub-classes that the examiner searched in the course of the examination.[155] Patent examiners used to manually perform these searches, but now they are performed by using software on a computer, so there should be a way to import the information automatically.

At some point, the USPTO should eliminate the steps where examiners must print out the filled out forms and office actions in order to have these documents scanned into the IFW system.

4. Eliminate Interference Searches

The USPTO requires examiners to perform an interference search on any application that is in condition for allowance.[156] If the examiner finds an interfering application or issued patent, then an interference is declared, and the application is transferred to the BPAI for interference proceedings.[157]

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[152] MPEP, *supra* note 26, § 1302.09, at 1300-8–9.

[153] MPEP, *supra* note 26, § 1302.04, at 1300-8.

[154] MPEP, *supra* note 26, § 719.05, at 700-311.

[155] MPEP, *supra* note 26, § 1302.09, at 1300-9.

[156] MPEP, *supra* note 26, § 1302.08, 2304.01, at 1300-8, 2300-100.

[157] MPEP, *supra* note 26, § 2301, at 2300-1.

Given the extremely small number of interference proceedings conducted every year, it is wasteful to require examiners to perform these searches. This is especially true given that the USPTO triggers few interferences. The USPTO issued over 162,000 utility patent applications in fiscal year 2006,[158] yet only about eighty-two interference proceedings were declared last year (derived by subtracting the forty-seven *inter-partes* reexamination proceedings[159] from the 129 total *inter-partes* proceedings declared).[160] Even if we assume that all of the interference proceedings were triggered by examiners' searches, rather than by applicants, we have a ratio of one interference triggered per 2,000 allowed patent applications.[161]

Assuming a fifteen-minute interference search per issued application, these searches cost 40,500 examiner hours spent just to trigger eighty-two interference proceedings.[162] This is the annual work of twenty full-time examiners.[163] The average examiner is at a GS-12 pay grade.[164] The 2006 salary for a GS-12 ranged from

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[158] U.S. PATENT AND TRADEMARK OFFICE, PERFORMANCE AND ACCOUNTABILITY REPORT FISCAL YEAR 2006, TABLE 6: PATENTS ISSUED (2006), *available at* http://www.uspto.gov/web/offices/com/annual/2006/50306_table6.html.

[159] U.S. PATENT AND TRADEMARK OFFICE, PERFORMANCE AND ACCOUNTABILITY REPORT FISCAL YEAR 2006, TABLE 13B: INTER PARTES REEXAMINATION (2006), *available at* http://www.uspto.gov/web/offices/com/annual/2006/50313b_table13b.html.

[160] U.S. PATENT AND TRADEMARK OFFICE, PERFORMANCE AND ACCOUNTABILITY REPORT FISCAL YEAR 2006, BPAI PROCESS PRODUCTION REPORT (2006), *available at* http://www.uspto.gov/web/offices/dcom/bpai/docs/process/fy2006.htm.

[161] (82 interferences / 162,000 issued patents).

[162] (162,000 issued patents x 15 minutes/ patent) / (60 minutes / hour).

[163] (40,500 examiner hours) / (2,000 hours per man year). A man-year is usually calculated as 2,000 hours.

[164] *See also* OIG REPORT, *supra* note 110, at 33 (providing the numbers of examiners at different GS levels between the years 1998 and 2003). We derived the average (mean) examiner level of GS-12 for 2003 based on these statistics. For the entire time span between 1998 and 2003, the average GS level was a little lower — around 11.80. *See id.*

approximately $67,000 to $87,000.[165] The salaries of 20 such examiners would range from $1.3 million to $1.7 million. As the size of the patent corps grows, so will the amount of time the corps spends performing interference searches, and the corresponding expense at well.

It is debatable whether this money is well spent. First, the current broad definition of an interference makes searching difficult.[166] It is not clear that a fifteen-minute search is sufficient. Moreover, this time would be better spent searching for prior art or reviewing applicant's claims or arguments. Since many applicants trigger interference proceedings by copying the claims of another applicant, or initiate the interference proceedings on their own, it would be much more cost effective to eliminate the interference searches completely, and formally shift the interference search burden onto the applicants.[167]

Part VI—Further Research

We feel that the following reforms have some merit, but are beyond the scope of this article, and will require further research.

1. Deferred Examination and Accelerated Examination

The USPTO has proposed several interesting reforms, such as offering the options of deferred examination and accelerated examination.[168] The deferred examination

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[165] Patent Office Prof'l Ass'n, Special Salary Rate Table (2006), *available at* http://www.popa.org/txt/salary2006.txt.

[166] *See* MPEP, *supra* note 26, § 2301.03, at 2300-3 ("A claim of one inventor can be said to interfere with the claim of another inventor if they each have a patentable claim to the same invention." Several examples of interfering claims follow.).

[167] As an aside, a change to a first-to-file system (instead of the current first-to-invent system) would completely eliminate interference proceedings and their associated searches costs.

[168] *See* MPEP, *supra* note 26, § 708.02(a), at 700-139. *See also* Lucas, *supra* note 3, at 4-18.

reform may be particularly beneficial, because it creates a new lowest priority level. According to the proposals, an applicant will be able to elect to defer examination, as well as paying examination fees, for several years.[169] Moreover, an applicant would be able to activate examination at any time, and a third party could activate examination after publication.[170]

Such a policy could be beneficial if a high percentage of applicants who elect to defer examination, abandoning the application before examination. We would need to significantly modify our queuing model in order to estimate what impact such a reform would have on the patent system

For example, one necessary modification would be to incorporate a preemptive queue into the model. According the proposed system, a deferred patent application that is "activated" would jump to the front of the unexamined application queue. Such an arrangement would complicate the queuing time calculations, because these "activated" applications would, in essence, cut in front of all the later-filed regular new applications waiting to be examined. The result would be a longer queuing time for all the later-filed regular new applications waiting in the queue. The amount of delay would depend on the number of activated deferred applications.

Accelerated examination,[171] on the other hand, requires a different set of modifications to the model. We do not know at which level of priority these new applications, and their amendments, are currently considered. If their priority levels are

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[169] Lucas, *supra* note 3, at 13.

[170] Lucas, *supra* note 3, at 13.

[171] MPEP, *supra* note 26, § 708.02(a), at 700-139.

higher than regular new and regular amended applications, then it will be necessary to incorporate these added priority levels into the priority queuing model.

2. Mandated Examiner Interviews

Currently, the USPTO requires examiners to telephone the applicant's attorney in most instances before issuing a restriction.[172] Only if this attempt fails does the examiner mail a restriction requirement.[173]

During the 1994 fiscal year, a USPTO pilot program applied the same requirement to cases that could be allowed with an examiner's amendment.[174] The stated objective of the pilot program was to "result in a decrease in the number of office actions per application, and in swifter prosecution. . ."[175] This policy remains in place today.[176] The USPTO should also consider a policy whereby the examiner makes similar phone calls before the first office action.

The primary problem with requiring examiner phone calls to applicants before drafting a first office action is that the applicants do not have access to the prior art that the examiner is considering. One obvious solution would be for the examiner to e-mail

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[172] MPEP, *supra* note 26, § 812.01, at 800-56. ("However, no telephone communication need be made where the requirement for restriction is complex, the application is being prosecuted by the applicant *pro se*, or the examiner knows from past experience that an election will not be made by telephone.").

[173] MPEP, *supra* note 26, § 812.01, at 800-56.

[174] U.S. Patent and Trademark Office, 1994 HIGHLIGHTS 9 (2004), http://www.uspto.gov/web/offices/com/annual/1994/pg6-16.pdf.

[175] *Id.*

[176] MPEP, *supra* note 26, § 812.01, at 800-56–57.

the prior art files, or a list of patent numbers, to the applicant a few days before the telephone interview.

Under current rules, however, the examiner cannot correspond by e-mail because the USPTO forbids examiners from responding via e-mail to any correspondence containing information subject to the confidentiality requirement set forth in 35 U.S.C. § 122 (2006) unless there is a written authorization of record in the patent application by the applicant.[177]

Because the USPTO now publishes applications eighteen months after filing and at that point the file wrapper is opened to the public, the USPTO policy limiting e-mail correspondence does not makes sense.[178] A policy encouraging telephone conversations before the first office action would spur more compact prosecution and result in quicker resolution of some cases. The examiner could always mail a non-final rejection if an agreement is reached with the applicant. Such a policy would increase the USPTO throughput and help to reduce the backlog.

It is interesting to note that under the requirements of the new accelerated examination procedure, the applicant is required to agree to an interview, possibly before the first office action, to discuss the prior art and potential objections or rejections.[179]

3. Changing Examination Time

Another possible way to increase the throughput of the system is to reduce the examining time per application. This change would increase the throughput of the system, but comes at a high cost – a less thorough examination.

[177] MPEP, *supra* note 26, § 502.03, at 500-20.

[178] MPEP, *supra* note 26, § 1120, 1128, at 1100-8, 1100-22.

[179] MPEP, *supra* note 26, § 708.02(a)(I)(G), at 700-140.

Previous discussions about examination time have usually revolved around the issue of *increasing* examining time rather than *decreasing* it.[180] Patent quality, rather than patent pendency or patent system throughput, has been the headline issue.

On the other hand, increasing the examination time without making any other reforms is also a bad idea. The USPTO currently does not have the service capacity to process its workload. Reducing the service capacity by increasing the examination time would only worsen the situation. Even in the best case scenario, the USPTO would have to hire many more examiners just to compensate for the increased examination time.[181] This is not to speak of the thousands of examiners it has already hired recently just to keep up with backlog of applications. At some point, the bottleneck becomes finding enough qualified engineers, rather than finding enough funds for the system.[182]

One way to increase examining time, as previously proposed by the USPTO, would be to outsource the patent examiners' search function to commercial vendors so that examiners could reallocate the time previously spent on searching to other tasks.[183] Splitting up the search and non-search examination functions, however, could negate any quality benefit arising from the increased total examination time per case.[184]

A related issue is determining how a change in the examination time would affect the quantity and scope of issued patents. One author estimated that doubling the

[180] Mark A. Lemley, *Rational Ignorance at the Patent Office*, 95 NW. U. L. REV.1495, 1508 & n.56 (2001), *available at* http://ssrn.com/abstract=261400 [hereinafter *Rational Ignorance*].

[181] *See id.* at 1508 n.57, 1509 n.60 (discussing the need to hire additional examiners).

[182] *See id.* at 1508 & n.57 (suggesting raising applicants' fees).

[183] *Fee Modernization Act Hearing*, *supra* note 1, at 63, 66.

[184] *Fee Modernization Act Hearing*, *supra* note 1, at 63.

examination time would decrease the number of issued patents by ten percent.[185] Others suggest that in addition to decreasing the number of issued patents, increasing examination time would also narrow the scope of issued patents.[186] Decreasing examination time, in order to increase the USPTO throughput, would have the opposite effect.

Conclusion and Note from the Authors

We were surprised by the results of the simulation. We expected the results to show starvation of the priority queue, caused by the RCEs and continuations. Instead, we got the unexpected result that the large number of non-final rejections per round of prosecution is the major cause of the backlog of applications.

Given the limitations of time and scarcity of data, our model was very simple in terms of mathematical complexity. A more detailed analysis was beyond the scope of this modest student note. The authors hope that this note will encourage further research along these lines, both inside and outside the USPTO.[187]

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[185] *Rational Ignorance*, *supra* note 180, at 1509.

[186] E-mail from Matthew P. Hodges to author and Samson Vermont, Assistant Professor, George Mason University School of Law (Dec. 15, 2006, 5:17 p.m.) (on file with author).

[187] The Authors' MATLAB source code is available upon request.

Improving Patent Examination Efficiency and Quality:

An Operations Research Analysis of the USPTO, Using Queuing Theory

By Ayal Sharon* and Yifan Liu**

Appendices

APPENDIX I—FOUNDATIONAL FORMULAS

1. Formula for Mean Length of Queue (L)

Let π_j be the steady-state probability that j items will be present.

If $\rho<1$, then we have steady-state probability $\pi_j = \rho_j (1 - \rho)$, so the mean length of the queue is[1]

$$L = \sum_{j=0}^{\infty} j\pi_j = \frac{\lambda}{\mu - \lambda}.$$

2. Priority Queue Formulas

We assume n types of applications with distinct priority levels. We label the highest priority level as level 1, and lowest as level n. For level k, denote the arrival rate as λ_k, and service rate as μ_k. The traffic intensity for the entire system is

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[1] *See* WAYNE L. WINSTON, OPERATIONS RESEARCH: APPLICATIONS AND ALGORITHMS 1074 (4th ed. 2004) [hereinafter WINSTON].

$\rho = \lambda_1/\mu_1 + \lambda_2/\mu_2 + ... + \lambda_n/\mu_n$.[2] Remember that only if ρ<1 can the queue reach steady-state. Otherwise, it becomes saturated and overwhelms the system.

When ρ<1, the mean steady-state number of type k items in the queue is L_{qk}. The mean steady-state number of type k items in the system is L_k. The mean waiting time spent in the queue by a type k item is W_{qk}, and the mean waiting time spent in the system by a type k item is L_k. Then from queuing theory:[3]

$$W_{qk} = \frac{\sum_{k=1}^{n} \lambda_k E(S_k^2)/2}{(1-a_{k-1})(1-a_k)}$$

$$L_{qk} = \lambda_k W_{qk}$$

$$W_k = W_{qk} + \frac{1}{\mu_k}$$

$$L_k = \lambda_k W_k$$

where $a_0 = 0$ and:

$$a_k = \sum_{i=1}^{k} \frac{\lambda_i}{\mu_i}.$$

These formulae hold when all types of items have different priority. However, when a few different types of items have the same priority, with different arrival and service rate, the situation will be more complicated. The derivation of those formulae follows.

Suppose we have n different priority levels, and in each level k, we have m_k different types of items with mean arrival rate λ_{kj} and mean service rate μ_{kj}, $j=1,...,m_k$.

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[2] *See id.* at 1127 (referencing the equation above eq.62).

[3] *Id.* at 1127, 1130.

Then, we find the total arrival rate, weighted mean service rate, and square of service time for each priority level, which are

$$\lambda_k = \sum_{j=1}^{m_k} \lambda_{kj}$$

$$\mu_k = \frac{\sum_{j=1}^{m_k} \mu_{kj}\rho_{kj}}{\sum_{j=1}^{m_k} \rho_{kj}}$$

$$E(S_k^2) = \frac{\sum_{j=1}^{m_k} E(S_{kj}^2)\rho_{kj}}{\sum_{j=1}^{m_k} \rho_{kj}}$$

where $\rho_{kl} = \lambda_{kj} / \mu_{kj}$ is the weight for type *j* item in level *k*.

Then, using the formulae for distinct priority levels and noticing that $E(S_{kj}^2) = 2 / \mu_{kj}^2$, we get the formulae needed for our problem.

$$W_{qkj} = \frac{\sum_{k=1}^{n} \lambda_k E(S_k^2)/2}{(1-a_{k-1})(1-a_k)}$$

$$L_{qkj} = \lambda_{kj} W_{qkj}$$

$$W_{kj} = W_{qkj} + \frac{1}{\mu_{kj}}$$

$$L_{kj} = \lambda_{kj} W_{kj}.$$

where a_k , λ_k , μ_k and $E(S_k^2)$ are as defined above.

APPENDIX II—PARAMETERS USED IN THE MODEL

In this section, we present all the parameters that we use in the following sections of the model. Most of the parameters come directly from published data, while a few are based on reasonable assumptions.

Application Data	**Description**	**Derivation**	**Value**
Reg New	Regular New Applications	See footnote [4]	254,000
RCE	Total RCEs	See footnote [5]	53,000
1st RCE	1st RCE	See footnote [6]	43,000
2nd RCE	2nd or Subsequent RCEs	See footnote [7]	10,000
Cont	Total Continuations + Divisionals	See footnote [8]	63,000
1st Cont	1st Continuation	See footnote [9]	32,700
2nd Cont	2nd or Subsequent Continuations	See footnote [10]	11,800
Divs	Divisional Applications	See footnote [11]	18,500
Special New	Special New Applications	See footnote [12]	1,200
Appeal	Appealed Applications	See footnote [13]	2,834

[4] *See* Changes to Practice for Continuing Applications, Requests for Continued Examination Practice, and Applications Containing Patentably Indistinct Claims, 71 Fed. Reg. 48, 50 (proposed Jan. 3, 2006) (to be codified at 37 C.F.R. pt. 1) (providing data that in fiscal year 2005, the USPTO received 317,000 nonprovisional applications, of which approximately 63,000 were continuing applications).

[5] *Id.*

[6] *See id.* (providing data that USPTO received 53,000 total requests for continued examination, of which, 10,000 were second or subsequent requests).

[7] *Id.*

[8] *Id.*

[9] *See id.* (providing data that USPTO received 63,000 total continuing applications, of which 18,500 were divisional applications and 11,800 were second or subsequent continuation/CIP applications).

[10] *Id.*

[11] *Id.*

[12] Changes to Practice for the Examination of Claims in Patent Applications, 71 Fed. Reg. 61, 63 (proposed Jan. 3, 2006) (to be codified at 37 C.F.R. pt. 1).

[13] U.S. PATENT AND TRADEMARK OFFICE, PERFORMANCE AND ACCOUNTABILITY REPORT FISCAL YEAR 2005, TABLE 14: SUMMARY OF CONTESTED PATENT CASES (2006), *available at* http://www.uspto.gov/web/offices/com/annual/2005/060414_table14.html.

Other Published Parameters	Description	Derivation	Value
N	Number of examiners	See footnote [14]	4,215
B	Probability Examiner affirmed at pre-appeal	See footnote [15]	0.43
c_p	Mean number of non-final rejections per parent application	See footnote [16]	1.6

Personally Estimated Parameters	Description	Derivation	Value
P_1	Probability of only one invention in an application	Personal estimation	0.98
p_m	Probability applicant files after-final amendment	Personal estimation	0.20
(i_2 / i_1)	Ratio of probability a patent issues in the second or later round of prosecution, divided by probability it issues in the first round	Personal estimation	1.5
p_x	Percentage of applications abandoned after the final rejection (rather than after a non-final rejection)	Personal estimation	0.95

Calculated Parameters	Description	Derivation	Value
hr	Examiner hours per year	= 48 weeks * 40 hours/week	1,920
λ	Hourly arrival rate of new applications per examiner	= Reg New / (N*hr)	0.0314
d	Mean number of inventions per application	= 1+ (Divs / (Reg New + 1st Cont + 2nd Cont + RCE))	1.0526
p_{sf}	Probability application filed with petition to make special	= Special New / Reg New	0.0047
C	Expected number of 1st generation continuation children created during non-final status	= 1st Cont / (Reg New + RCE + Appeal/ β)	0.1043
M_2	Mean number of 2nd or subsequent generation of continuation children per new application	= 2nd Cont / Reg New	0.0465

[14] *See* John Doll, Comm'r for Patents, U.S. Patent and Trademark Office, Address at Chicago Town Hall Meeting 20 (Feb. 1, 2006), *available at* http://www.uspto.gov/web/offices/pac/dapp/opla/presentation/chicagoslides.ppt (power point presentation) (N = FY 05 BOY Examiner Staff + FY 05 Hiring - FY 05 Attrits).

[15] *See generally* U.S. PATENT AND TRADEMARK OFFICE, PATENT PUBLIC ADVISORY COMMITTEE MEETING 41−45 (Oct. 25, 2005), *available at* http://www.uspto.gov/web/offices/com/advisory/acrobat/ppac_transcript_102505.pdf.

[16] *See* OFFICE OF INSPECTOR GEN., U.S. DEP'T. OF COMMERCE, FINAL INSPECTION REPORT NO. IPE-15722/SEPTEMBER 2004, USPTO SHOULD REASSESS HOW EXAMINER GOALS, PERFORMANCE APPRAISAL PLANS, AND THE AWARD SYSTEM STIMULATE AND REWARD EXAMINER PRODUCTION, 17 fig.12 (2004), *available at* http://www.oig.doc.gov/oig/reports/2004/USPTO-IPE-15722-09-04.pdf (actions per application—extrapolated to 2005).

We have five other parameters to be estimated— $p_f^{(1)}$, $p_f^{(2)}$, $p_e^{(1)}$, $p_e^{(2)}$, and p_a. Because these parameters cannot be derived directly from the data, we set up five equations containing these five unknown variables from the data and solve for them.

First, we have 43,000 first round RCEs for 254,000 new applications and 32,700 + 11,800 child continuation applications, which means:

$$298500E^{(1)} = 298500dp_f^{(1)}p_e^{(1)} = 43000,$$

plug in $d = 1.0526$, we get:

$$p_f^{(1)}p_e^{(1)} = 0.1369$$

(Eq. 1)

Second, we have 10,000 second and later rounds of RCE for these 298,500 applications, which means:

$$298500E^{(2+)} = 298500(dp_f^{(1)}p_e^{(1)})\left[\frac{dp_f^{(2)}p_e^{(2)}}{1-dp_f^{(2)}p_e^{(2)}}\right] = 10000,$$

plug in the value of *d* and (Eq. 1), we have:

$$\frac{dp_f^{(2)}p_e^{(2)}}{1-dp_f^{(2)}p_e^{(2)}} = 0.2325,$$

$$dp_f^{(2)}p_e^{(2)} = 0.1886,$$

hence:

$$p_f^{(2)}p_e^{(2)} = 0.1792.$$

(Eq. 2)

Third, the probability that a patent issues in the second or later round of prosecution (denoted by i_2) is higher than the probability it issues in the first round (denoted by i_1). We personally estimated this ratio as 1.5. That is, $i_2 = 1.5 i_1$. Also, since the average number of office actions for each round is estimated to be 2.6:[17]

$$(1-i_1)^{2.6} = p_f^{(1)}$$

$$(1-i_2)^{2.6} = p_f^{(2)}$$

That is to say:

$$i_1 = 1 - \log_{2.6} p_f^{(1)},$$

$$i_2 = 1 - \log_{2.6} p_f^{(2)}.$$

Since $i_2 = 1.5 i_1$, we have:

$$1 - \log_{2.6} p_f^{(2)} = 1.5(1 - \log_{2.6} p_f^{(1)}),$$

which yields:

$$(p_f^{(1)})^{1.5} = 2.6^{0.5} p_f^{(2)}$$

(Eq. 3)

Fourth, we have 2834 appeals sent to BPAI, which means:

$$298500 A\beta = 298500 \left[dp_f^{(1)} + dp_f^{(1)} p_e^{(1)} \frac{p_f^{(2)}}{1 - dp_f^{(2)} p_e^{(2)}} \right] p_a \beta = 2834,$$

plug in β, d and equations (1),(2), we get:

$$(1.0526 p_f^{(1)} + 0.1776 p_f^{(2)}) p_a = 0.0221$$

(Eq. 4)

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[17] *See id.* (actions per application—extrapolated to 2005). This value is confirmed by anecdotal evidence. *See* Iowa State University Research Foundation, Inc. Office of Intellectual Property & Technology Transfer, Patents and the Patent Process 7 (Feb. 3, 2007) ("*How many office actions will occur?* It is reasonable to expect to receive three office actions per application. If continuations are filed, for example, there will be additional office actions issued.") http://www.techtransfer.iastate.edu/en/for_iowa_state/educational_resources/patents_and_the_patenting_process.cfm.

Fifth, we have 96,176*1.1=105,794[18] abandoned applications. We estimate that the percentage of applications abandoned after the final rejection (rather than after a non-final rejection) is p_x = 95%, which means:

$$298500\left[p_f^{(1)}(1-p_a-p_e^{(1)})\right]+53000\left[\frac{p_f^{(2)}(1-p_a-p_e^{(2)})}{1-p_f^{(2)}p_e^{(2)}}\right]+\frac{2834}{\beta}\left[p_f^{(2)}(1-p_a)\right]=105794*0.95=100504,$$

plug in equations (1) and (2), and after some arrangement, we get:

$$(298.5p_f^{(1)}+71.1712p_f^{(2)})(1-p_a)=152.9395$$

(Eq. 5)

Solving equations (Eq.1) to (Eq.5), we get the five parameters listed in the following table:

Solved Parameters	**Description**	**Value**
$p_f^{(1)}$	probability to reach final rejection in the first round	0.4841
$p_f^{(2)}$	probability to reach final rejection in the second or later round	0.2089
$p_e^{(1)}$	probability to choose RCE after the first round	0.2828
$p_e^{(2)}$	probability to choose RCE after the second or round	0.8578
p_a	probability to choose appeal	0.0404

[18] U.S. PATENT AND TRADEMARK OFFICE, PERFORMANCE AND ACCOUNTABILITY REPORT FISCAL YEAR 2005, TABLE 1: SUMMARY OF PATENT EXAMINING ACTIVITIES (2006), *available at* http://www.uspto.gov/web/offices/com/annual/2005/060401_table1.html (abandonment data from 2003 extrapolated to 2005).

APPENDIX III—THE DETAILED MODEL

1. Estimating the Number of Arrivals, Sorted by Type of Application

Our problem is a priority queuing model with branching feedback. Since there are several different priority levels and each level receives different types of applications, it is necessary to estimate separately the arrival rate of each type of application.

In order to calculate the arrival rates of the different types of applications, we make the following assumptions: (1) we define a *round* of prosecution as all the non-final rejections until, and including, the final rejection; (2) there can be several non-final rejections before a final rejection is issued; (3) after a final office action, the applicant may choose to RCE, appeal, or abandon; and (4) once the applicant chooses to appeal, there are typically no more RCEs (despite the rule that applicants can file an RCE if the BPAI affirms the Examiner's rejection).

A. RCE

For each brand new application, the expected number of RCEs it will generate after the first round of prosecution is:

$$E^{(1)} = dp_f^{(1)} p_e^{(1)}$$

where d is the expected number of inventions in an application and $p_f^{(1)}$ is the probability for an application to reach the post-final stage in the first round (i.e., the probability the application will not be allowed or abandoned before a final-decision). The parameter $p_e^{(1)}$ is the probability that an applicant will file an RCE after the first round of prosecution.

For the sake of the simplicity of the model, we assume that these probabilities remain constant for subsequent rounds of prosecution[19] and denote them as $p_f^{(2)}$ and $p_e^{(2)}$ respectively for all rounds starting after the second round. The expected total number of RCEs after the second round of prosecution is:

$$E^{(2)} = dp_f^{(1)} p_e^{(1)} dp_f^{(2)} p_e^{(2)}$$

and similarly, for all subsequent rounds, is:

$$E^{(k)} = dp_f^{(1)} p_e^{(1)} (dp_f^{(2)} p_e^{(2)})^{(k-1)}.$$

We take the sum of the series and we have the number of RCEs that the USPTO proposed reform is targeting to eliminate:

$$E^{(2+)} = dp_f^{(1)} p_e^{(1)} \frac{dp_f^{(2)} p_e^{(2)}}{1 - dp_f^{(2)} p_e^{(2)}}.$$

Therefore, the total number of RCEs currently generated by a new application is:

$$E = E^{(1)} + E^{(2+)} = dp_f^{(1)} p_e^{(1)} \frac{1}{1 - dp_f^{(2)} p_e^{(2)}}.$$

B. Appeal

An applicant can file an appeal immediately after the first round of prosecution, or alternatively, can appeal after one or more additional rounds of prosecution. (The applicant obtains additional rounds by filing RCEs).[20] For simplicity, we neglect the instances when an applicant files an appeal more than once in the course of prosecuting

[19] There is an argument that this is not the case. It may be that in subsequent rounds of prosecution, the probability of allowance rises, so the probability of final rejection falls. Also, it is possible that the probability of the applicant filing an RCE falls in the second and subsequent rounds.

[20] Changes to Practice for Continuing Applications, Requests for Continued Examination Practice, and Applications Containing Patentably Indistinct Claims, 71 Fed. Reg. 48, 50 (proposed Jan. 3, 2006) (to be codified at 37 C.F.R. pt. 1).

an application.[21] We assume that an applicant files an appeal only once. Suppose at the stage of final-rejection, the probability to choose appeal is p_a, then, for each brand new application, the expected number of appeals it will generate (ignoring any possible child continuation applications) is

$$A = dp_f^{(1)} p_a + Ep_f^{(2)} p_a.$$

C. Continuations—Parent Application Remaining Alive

Regular new applications, RCEs, and appealed applications can all spawn *child* continuation applications. Some of the *parent* applications remain *alive* in prosecution and feed back into the arrival queue if the continuation is filed immediately after receiving a non-final rejection. In the case of appealed applications, this can happen if a pre-appeal conference overturns the examiner.[22] If we let n_p be the number of parent applications that are alive in each round due to non-final rejections, then the total number of living parent applications is

$$P = (d + E + A)n_p$$

D. Continuations—Child Applications

Now we consider child applications. For each type of application (regular new, RCE, or appeal), suppose the expected number of first generation children it generates is c. Then for each brand new application, the expected total number of first generation children is:

[21] Multiple appeal briefs can be filed in an application when the examiner reopens prosecution after being reversed at a pre-appeal conference, followed by the applicant filing another appeal.

[22] About 60% of pre-appeal conferences result in the reversal of the examiner. *See generally* U.S. PATENT AND TRADEMARK OFFICE, PATENT PUBLIC ADVISORY COMMITTEE MEETING 41− 45 (October 25, 2005), *available at* http://www.uspto.gov/web/offices/com/advisory/acrobat/ppac_transcript_102505.pdf.

$$M_1 = (d + E + A)c.$$

For simplicity, if we let M_2 denote the total number of second and lower generation of children, then the total number of offspring including itself is $1 + M_1 + M_2$.

2. Priority Queue Arrival and Service Rates

Most queuing models have two very important parameters: mean *arrival* rate (λ) and mean *service* rate (μ).[23] Mean arrival rate is the average rate at which items arrive, and is measured in items per hour or some similar metric.[24] Mean service rate is the rate at which the server completes processing arriving items.[25] The inverse of the mean service rate is the mean service time (1/μ).

Both the arrival rate and service rate are random variables. In order to simplify our problem, we assume no bulk arrivals (i.e., multiple items arrive at exactly the same instant), and no memory (past arrivals do not affect future arrivals). According to probability theory, in this situation, the number of arrivals in a unit time length fits a Poisson distribution with mean λ.[26] Therefore, the number of arrivals in any time interval of length t is λt.[27] Regarding the service rate, for computational simplicity, we assume the no-memory property, so that the service time follows an exponential distribution with

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[23] EDWARD D. LAZOWSKA ET AL., QUANTITATIVE SYSTEM PERFORMANCE 5 (Prentice-Hall 1984) (refers to "mean arrival rate" as "workload intensity" and to "mean service rate" as "throughput"), *available at* http://www.cs.washington.edu/homes/lazowska/qsp/. By convention, the symbol for mean arrival rate is (λ), and for mean service rate is (μ).

[24] *Id.*

[25] *Id.*

[26] WAYNE L. WINSTON, OPERATIONS RESEARCH: APPLICATIONS AND ALGORITHMS, 1055–56 (4th ed. 2004).

[27] *Id.*

parameter μ. That is, the mean service time for one item is μ^{-1} and mean service rate (number of items served in unit time) is μ.[28]

For Poisson distribution, the answer is already given in the paper written—*no bulk arrivals (i.e., multiple items arrive at exactly the same instant) and no memory (past arrivals do not affect future arrivals*—these are the reasons for Poisson distribution, and these assumption are roughly true in reality.

These two factors, λ and μ, directly influence the queue length (L) and the waiting time (W). The queue length (L) grows over time if $\lambda \geq \mu$. In other words, the queue grows when the mean arrival rate is larger than the mean service rate. This represented by the traffic intensity variable $\rho = \lambda / \mu$. When $\rho \geq 1$ (in other words, $\lambda \geq \mu$), then no steady-state can be reached and the system is overwhelmed. If, on the other hand, $\rho < 1$, then we can calculate the mean queue length (L).[29] In addition, Little's Law, $L = \lambda W$, gives the relation between mean queue length and mean waiting time.[30]

Based on the results in the previous section, we can list the arrival rate and service rate for all item types in the priority queue as shown in the following sections.

A. Priority Level 1—Special Amended Docket

We assume a one-hour service time for all items in this priority level, thus $\mu^{-1} = 1$ for all the different types of applications in this priority level.

For after-final amendments, the mean arrival rate and mean service time are as follows:

[28] *See id.* at 1054–55.

[29] The formula for mean length of queue (L) can be found on page three of the appendix.

[30] *See* WINSTON, *supra* note 26, at 1074-1077. *See also* LAZOWSKA, *supra* note 23, at 42-44.

$$\lambda_{11} = \lambda(1+M_1+M_2)(dp_f^{(1)} + (E+A)p_f^{(2)})p_m,$$

$$\mu_{11}^{-1} = 1,$$

where p_m is the probability applicants file after-final amendments.

For BPAI Decisions:

$$\lambda_{12} = \lambda(1+M_1+M_2)(dp_f^{(1)} + (E+A)p_f^{(2)})p_a\beta,$$

$$\mu_{12}^{-1} = 1,$$

where β is the probability an appeal is sent to the BPAI.

B. Priority Level 2—Regular Amended Docket

We assume a ten-hour service time for all items in this priority level, thus $\mu^{-1} = 10$ for all the different types of applications in this priority level.

For responses to non-final rejections:

$$\lambda_{21} = \lambda P(1+M_1+M_2),$$

$$\mu_{21}^{-1} = 10.$$

For RCEs:

$$\lambda_{22} = \lambda E(1+M_1+M_2),$$

$$\mu_{22}^{-1} = 10.$$

For appeal briefs:

$$\lambda_{23} = \lambda(1+M_1+M_2)(dp_f^{(1)} + (E+A)p_f^{(2)})p_a\beta,$$

$$\mu_{23}^{-1} = 10.$$

For elections:

$$\lambda_{24} = \lambda(1 + M_1 + M_2)(1 + E)(1 - p_1),$$

$$\mu_{24}^{-1} = 10,$$

where p_1 is the probability for an application to have exactly one invention.

For appeals:

$$\lambda_{25} = \lambda A(1 + M_1 + M_2),$$

$$\mu_{25}^{-1} = 10.$$

C. Priority Level 3—Special New Docket

We assume a ten-hour service time for all items in this priority level, thus $\mu^{-1} = 10$ for all the different types of applications in this priority level. The special new docket contains three types of applications: (1) new applications that the applicants have petitioned to make special; (2) divisional applications; (3) and child applications.

For cases petitioned to make special, p_{sf} is the probability for a new application to be with petition to make special.

$$\lambda_{31} = \lambda p_{sf},$$

$$\mu_{31}^{-1} = 10,$$

For divisional applications:

$$\lambda_{32} = \lambda(1 + M_1 + M_2)(1 + E)(d - 1),$$

$$\mu_{32}^{-1} = 10.$$

For child applications (continuations and continuations-in-part):

$$\lambda_{33} = \lambda(M_1 + M_2),$$

$$\mu_{33}^{-1} = 10.$$

D. Priority Level 4—Regular New Docket

For regular new applications without petition to make special:

$$\lambda_{41} = \lambda(1 - p_{sf}),$$

$$\mu_{41}^{-1} = 10.$$

APPENDIX IV—SENSITIVITY ANALYSIS

In this section, we discuss the sensitivity analysis results. The purpose of sensitivity analysis is to determine which variables are the most important. In other words, the purpose of sensitivity analysis is to determine to which parameters *the model* is most sensitive.

We performed sensitivity analysis on a small subset of the variables in our model. These included three *personally estimated parameters*: the probability that applications abandoned during prosecution are abandoned after the final rejection rather than after a non-final rejection (p_x), and the ratio of probability a patent issues in the second or later round of prosecution, divided by probability it issues in the first round (i_2 / i_1), and the probability applicant files after-final amendment (p_m).

In addition, and perhaps most importantly, we performed sensitivity analysis on the mean number of non-final rejections per parent application (c_p).

Changing the value of p_m would not change the values of the five solved parameters: $p_f^{(1)}$, $p_f^{(2)}$, $p_e^{(1)}$, $p_e^{(2)}$, and p_a, but would change the final results. Changing any of the other three parameters (p_x, c_p, or [i_2 / i_1]) would change the values of both the five solved parameters and the final results.

For each analysis, we could only do the sensitivity analysis for one parameter—such as p_m—while keeping the other parameters at their original values. Therefore, in the tables below, we modify the values for only one parameter for each scenario.

From the tables below we can see that for each fixed parameter, our conclusion still holds: restricting rounds of continuing applications (*children*) or RCE will not help to reduce the saturation of the patent system. The sum of the rhos in the priority queues remains greater than one, which means the system is saturated. The greatest contributor to the traffic intensity is consistently ρ_2, which is the regular amended docket.

Reducing the arrival rate of items in this priority level is key to reducing the traffic intensity of the entire system. Reducing the number of non-final rejections in each round of prosecution helps substantially and brings the sum of the rhos below the critical value of one.

Changing the other parameters (p_x, p_m, or $[i_2 / i_1]$), such as limiting the number of RCEs to one, or reducing the non-final rejection, etc., has very little effect on the end result. These are non-sensitive parameters.

The parameter c_p, on the other hand, has a great effect on the final result. It is a sensitive parameter. This matches our original result, that the number of non-final rejection per round of prosecution is a key issue. It clearly makes a difference when the number varies between 1.2 and 2.0 (original was 1.6 for non-final, and 2.6 for non-final plus final, i.e. 1.6+1 = 2.6).

1. Sensitivity analysis of p_m

Changing p_m doesn't affect the parameters $p_f^{(1)}$, $p_f^{(2)}$, $p_e^{(1)}$, $p_e^{(2)}$, and p_a.

Pre-reform status quo:

	p_m =0.1	p_m =0.15	p_m =0.2	p_m =0.25	p_m =0.3
P_1	0.0024	0.0034	0.0044	0.0054	0.0065
P_2	0.8263	0.8263	0.8263	0.8263	0.8263
P_3	0.0799	0.0799	0.0799	0.0799	0.0799
P_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.2210	1.2220	1.2230	1.2240	1.2250

Allowing one round of RCE:

	p_m =0.1	p_m =0.15	p_m =0.2	p_m =0.25	p_m =0.3
ρ_1	0.0024	0.0034	0.0044	0.0054	0.0064
ρ_2	0.7911	0.7911	0.7911	0.7911	0.7911
ρ_3	0.0781	0.0781	0.0781	0.0781	0.0781
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.1840	1.1850	1.1860	1.1870	1.1880

Allowing no RCE:

	p_m =0.1	p_m =0.15	p_m =0.2	p_m =0.25	p_m =0.3
ρ_1	0.0022	0.0031	0.0041	0.0050	0.0059
ρ_2	0.6423	0.6423	0.6423	0.6423	0.6423
ρ_3	0.0703	0.0703	0.0703	0.0703	0.0703
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.0272	1.0281	1.0291	1.0300	1.0309

Allowing one generation of continuing applications (*children*):

	p_m =0.1	p_m =0.15	p_m =0.2	p_m =0.25	p_m =0.3
ρ_1	0.0023	0.0033	0.0043	0.0052	0.0062
ρ_2	0.7936	0.7936	0.7936	0.7936	0.7936
ρ_3	0.0645	0.0645	0.0645	0.0645	0.0645
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.1728	1.1738	1.1747	1.1757	1.1767

Allowing no continuing applications (*children*):

	p_m =0.1	p_m =0.15	p_m =0.2	p_m =0.25	p_m =0.3
ρ_1	0.0020	0.0029	0.0038	0.0046	0.0055
ρ_2	0.7020	0.7020	0.7020	0.7020	0.7020
ρ_3	0.0209	0.0209	0.0209	0.0209	0.0209
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.0373	1.0382	1.0390	1.0399	1.0408

Reducing the number of non-final rejections to one per round of prosecution:

	p_m =0.1	p_m =0.15	p_m =0.2	p_m =0.25	p_m =0.3
ρ_1	0.0028	0.0040	0.0053	0.0065	0.0077
ρ_2	0.5783	0.5783	0.5783	0.5783	0.5783
ρ_3	0.0818	0.0818	0.0818	0.0818	0.0818
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	0.9754	0.9766	0.9778	0.9790	0.9802

2. Sensitivity analysis of (i_2 / i_1)

Changes to the five solved parameters:

	(i_2 / i_1) =1.3	(i_2 / i_1) =1.4	(i_2 / i_1) =1.5	(i_2 / i_1) =1.6	(i_2 / i_1) =1.7
$\rho_f^{(1)}$	0.4765	0.4764	0.4841	0.4908	0.4966
$\rho_f^{(2)}$	0.2794	0.2417	0.2089	0.1805	0.1559
$\rho_e^{(1)}$	0.2928	0.2874	0.2828	0.2789	0.2757
$\rho_e^{(2)}$	0.6413	0.7415	0.8578	0.9928	1.1497*
p_a	0.0408	0.0406	0.0404	0.0403	0.0402

Pre-reform status quo:

	(i_2 / i_1) =1.3	(i_2 / i_1) =1.4	(i_2 / i_1) =1.5	(i_2 / i_1) =1.6	(i_2 / i_1) =1.7
ρ_1	0.0044	0.0044	0.0044	0.0044	0.0044
ρ_2	0.8263	0.8263	0.8263	0.8263	0.8263
ρ_3	0.0799	0.0799	0.0799	0.0799	0.0799
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.2230	1.2230	1.2230	1.2230	1.2230

Allowing one round of RCE:

	(i_2 / i_1) =1.3	(i_2 / i_1) =1.4	(i_2 / i_1) =1.5	(i_2 / i_1) =1.6	(i_2 / i_1) =1.7
ρ_1	0.0043	0.0043	0.0044	0.0044	0.0044
ρ_2	0.7910	0.7911	0.7911	0.7912	0.7912
ρ_3	0.0781	0.0781	0.0781	0.0781	0.0781
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.1858	1.1859	1.1860	1.1861	1.1861

Allowing no RCE:

	(i_2 / i_1) =1.3	(i_2 / i_1) =1.4	(i_2 / i_1) =1.5	(i_2 / i_1) =1.6	(i_2 / i_1) =1.7
ρ_1	0.0039	0.0040	0.0041	0.0041	0.0042
ρ_2	0.6417	0.6420	0.6423	0.6426	0.6428
ρ_3	0.0703	0.0703	0.0703	0.0703	0.0703
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.0283	1.0287	1.0291	1.0294	1.0296

Allowing one generation of continuing applications (*children*):

	(i_2 / i_1) =1.3	(i_2 / i_1) =1.4	(i_2 / i_1) =1.5	(i_2 / i_1) =1.6	(i_2 / i_1) =1.7
ρ_1	0.0042	0.0042	0.0043	0.0043	0.0043
ρ_2	0.7937	0.7936	0.7936	0.7936	0.7936
ρ_3	0.0645	0.0645	0.0645	0.0645	0.0645
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.1747	1.1747	1.1747	1.1747	1.1747

Allowing no continuing applications (*children*):

	$(i_2 / i_1) = 1.3$	$(i_2 / i_1) = 1.4$	$(i_2 / i_1) = 1.5$	$(i_2 / i_1) = 1.6$	$(i_2 / i_1) = 1.7$
ρ_1	0.0037	0.0038	0.0038	0.0038	0.0038
ρ_2	0.7020	0.7020	0.7020	0.7020	0.7020
ρ_3	0.0209	0.0209	0.0209	0.0209	0.0209
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.0391	1.0391	1.0391	1.0391	1.0391

Reducing the number of non-final rejections to one per round of prosecution:

	$(i_2 / i_1) = 1.3$	$(i_2 / i_1) = 1.4$	$(i_2 / i_1) = 1.5$	$(i_2 / i_1) = 1.6$	$(i_2 / i_1) = 1.7$
ρ_1	0.0053	0.0053	0.0053	0.0052	0.0052
ρ_2	0.5799	0.5790	0.5783	0.5777	0.5772
ρ_3	0.0819	0.0819	0.0818	0.0818	0.0818
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	0.9795	0.9785	0.9778	0.9771	0.9765

3. Sensitivity analysis of c_p

Changes to the five solved parameters:

	c_p =1.2	c_p =1.4	c_p =1.6	c_p =1.8	c_p =2.0
$\rho_f^{(1)}$	0.4805	0.4824	0.4841	0.4857	0.4871
$\rho_f^{(2)}$	0.2245	0.2163	0.2089	0.2023	0.1963
$\rho_e^{(1)}$	0.2849	0.2838	0.2828	0.2819	0.2810
$\rho_e^{(2)}$	0.7981	0.8286	0.8578	0.8859	0.9130
p_a	0.0405	0.0405	0.0404	0.0404	0.0404

Pre-reform status quo:

	c_p =1.2	c_p =1.4	c_p =1.6	c_p =1.8	c_p =2.0
ρ_1	0.0044	0.0044	0.0044	0.0044	0.0044
ρ_2	0.6412	0.7337	0.8263	0.9188	1.0113
ρ_3	0.0799	0.0799	0.0799	0.0799	0.0799
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.0379	1.1305	1.2230	1.3155	1.4081

Allowing one round of RCE:

	c_p =1.2	c_p =1.4	c_p =1.6	c_p =1.8	c_p =2.0
ρ_1	0.0043	0.0044	0.0044	0.0044	0.0044
ρ_2	0.6116	0.7014	0.7911	0.8809	0.9707
ρ_3	0.0781	0.0781	0.0781	0.0781	0.0781
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.0064	1.0962	1.1860	1.2758	1.3656

Allowing no RCE:

	c_p =1.2	c_p =1.4	c_p =1.6	c_p =1.8	c_p =2.0
P_1	0.0040	0.0040	0.0041	0.0041	0.0041
P_2	0.4861	0.5642	0.6423	0.7204	0.7985
ρ_3	0.0703	0.0703	0.0703	0.0703	0.0703
P_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	0.8729	0.9510	1.0291	1.1072	1.1853

Allowing one generation of continuing applications (*children*):

	c_p =1.2	c_p =1.4	c_p =1.6	c_p =1.8	c_p =2.0
P_1	0.0042	0.0043	0.0043	0.0043	0.0043
P_2	0.6159	0.7048	0.7936	0.8825	0.9714
P_3	0.0645	0.0645	0.0645	0.0645	0.0645
P_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	0.9970	1.0859	1.1747	1.2636	1.3525

Allowing no continuing applications (*children*):

	c_p =1.2	c_p =1.4	c_p =1.6	c_p =1.8	c_p =2.0
P_1	0.0038	0.0038	0.0038	0.0038	0.0038
P_2	0.5448	0.6234	0.7020	0.7806	0.8592
P_3	0.0209	0.0209	0.0209	0.0209	0.0209
P_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	0.8818	0.9604	1.0390	1.1177	1.1963

Reducing the number of non-final rejections to one per round of prosecution:

	c_p =1.2	c_p =1.4	c_p =1.6	c_p =1.8	c_p =2.0
P_1	0.0047	0.0050	0.0053	0.0055	0.0057
P_2	0.5599	0.5697	0.5783	0.5860	0.5928
P_3	0.0807	0.0813	0.0818	0.0823	0.0828
P_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	0.9576	0.9683	0.9778	0.9861	0.9936

4. Sensitivity analysis of p_x

Changes to the five solved parameters:

	$p_x = 90\%$	$p_x = 92.5\%$	$p_x = 95\%$	$p_x = 97.5\%$	$p_x = 99.5\%$
$\rho_f^{(1)}$	0.4607	0.4724	0.4841	0.4958	0.5051
$\rho_f^{(2)}$	0.1939	0.2014	0.2089	0.2165	0.2227
$\rho_e^{(1)}$	0.2971	0.2898	0.2828	0.2761	0.2710
$\rho_e^{(2)}$	0.9240	0.8898	0.8578	0.8277	0.8048
p_a	0.0425	0.0415	0.0404	0.0394	0.0387

Pre-reform status quo:

	$p_x = 90\%$	$p_x = 92.5\%$	$p_x = 95\%$	$p_x = 97.5\%$	$p_x = 99.5\%$
ρ_1	0.0042	0.0043	0.0044	0.0045	0.0046
ρ_2	0.8263	0.8263	0.8263	0.8263	0.8263
ρ_3	0.0799	0.0799	0.0799	0.0799	0.0799
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.2228	1.2229	1.2230	1.2231	1.2232

Allowing one round of RCE:

	$p_x = 90\%$	$p_x = 92.5\%$	$p_x = 95\%$	$p_x = 97.5\%$	$p_x = 99.5\%$
ρ_1	0.0042	0.0043	0.0044	0.0045	0.0044
ρ_2	0.7911	0.7911	0.7911	0.7911	0.7911
ρ_3	0.0781	0.0781	0.0781	0.0781	0.0781
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.1858	1.1859	1.1860	1.1861	1.1862

Allowing no RCE:

	$p_x = 90\%$	$p_x = 92.5\%$	$p_x = 95\%$	$p_x = 97.5\%$	$p_x = 99.5\%$
ρ_1	0.0039	0.0040	0.0041	0.0042	0.0042
ρ_2	0.6423	0.6423	0.6423	0.6423	0.6423
ρ_3	0.0703	0.0703	0.0703	0.0703	0.0703
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.0289	1.0290	1.0291	1.0291	1.0292

Allowing one generation of continuing applications (*children*):

	$p_x = 90\%$	$p_x = 92.5\%$	$p_x = 95\%$	$p_x = 97.5\%$	$p_x = 99.5\%$
ρ_1	0.0041	0.0042	0.0043	0.0044	0.0044
ρ_2	0.7936	0.7936	0.7936	0.7936	0.7936
ρ_3	0.0645	0.0645	0.0645	0.0645	0.0645
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.1745	1.1746	1.1747	1.1748	1.1749

Allowing no continuing applications (*children*):

	$p_x = 90\%$	$p_x = 92.5\%$	$p_x = 95\%$	$p_x = 97.5\%$	$p_x = 99.5\%$
ρ_1	0.0036	0.0037	0.0038	0.0038	0.0039
ρ_2	0.7020	0.7020	0.7020	0.7020	0.7020
ρ_3	0.0209	0.0209	0.0209	0.0209	0.0209
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	1.0389	1.0390	1.0390	1.0391	1.0392

Reducing the number of non-final rejections to one per round of prosecution:

	$p_x = 90\%$	$p_x = 92.5\%$	$p_x = 95\%$	$p_x = 97.5\%$	$p_x = 99.5\%$
ρ_1	0.0051	0.0052	0.0053	0.0053	0.0054
ρ_2	0.5805	0.5794	0.5783	0.5772	0.5764
ρ_3	0.0820	0.0819	0.0818	0.0818	0.0817
ρ_4	0.3124	0.3124	0.3124	0.3124	0.3124
Sum of rho	0.9799	0.9788	0.9778	0.9767	0.9759