A Swedish Perspective on the Prevention of Moisture Problems During the Building's Design Phase

Stephen Burke [1] **and Veronica Yverås** [2]
[1] Department of Building Physics, Lund Institute of Technology,
Box 118, 221 00, Lund, Sweden
stephen.burke@byggtek.lth.se
[2] Department of Building Physics, Chalmers University of Technology, Sweden
veronica.yveras@jm.se

Abstract. *Moisture problems in buildings are increasingly being reported in the mass media in Sweden, often leading to some controversial stories about companies and their building processes. Using building physics and building performance principles during the design stage can often prevent most problems from occurring. One of the big questions is, with all the available knowledge about designing a building, how can these problems still be occurring in new buildings? This paper explores this question by interviewing some engineering consultants on how they evaluate the performance of a building, and to what extent knowledge about building physics theory is being used during the design process to prevent moisture problems from occurring. It was found that building physics is not used extensively in the building industry due to many reasons. The lack of good design tools and the fact that clients do not request it are two main reasons. However, it was revealed that clients do not request it because they either have no interest in spending the extra money for a better design, or they do not know it is optional and just assume everything is taken account of in the final design. Furthermore, the consultants do not advise them on the available options applicable for their particular design. Due to the method used to analyse the interviews, an unexpected relationship between education level and their perceived level of awareness of building performance issues emerged. It appears that the higher the level of education of the consultant, the more they are aware of the impact of performance issues in a building's design. Their experience level does not appear significant in this relationship, however this cannot be proven and will require more studies to verify.*

Keywords: *building physics, building performance, interviews, tools, consultants, education, and economics*

1 Introduction

Moisture design appears to be a growing trend in Sweden. This can be explained by the attention from mass media that various projects around Sweden have been getting. Specifically, projects involving mould in buildings and moisture damage in newly constructed buildings, largely multi-family dwellings (Jelvefors 2002; Luthander 2001). This trend is increasing because the media has brought it to the attention of the public that the consultants do not perform a moisture analysis on a building's design during the design phase. The consultants admit that clients do not request moisture design because the clients assume that it is included in the normal design process (Arfvidsson and Sikander 2002, p. 14).

Building physics in Sweden is defined as the study of the transport of heat, moisture, and air through a building's envelope in relation to both the indoor and outdoor climate (Hagentoft 2001). It is a key area in the development of energy efficient, healthy, moisture safe and durable buildings. It is this field of science that focuses on the prevention of moisture problems during the design phase of a building. Please note that the Swedish definition of building physics does not include lighting and acoustics, unlike most other countries around the world.

In many countries, architects are responsible for the design and detailing of a building. In the Swedish building industry it is common that the architects are only responsible for the form and shape of a building and engineering consultants are responsible for the technical specifications. Recently, Sweden has seen an increase in the amount of mass-media attention that problematic buildings are getting; even to the point of being damaging for the companies involved in all phases of the construction (Luthander 2001; Jelvefors 2002; Samuelson and Wånggren 2002). One of the big questions is, with all the available knowledge about designing a building, how can these problems still be occurring in new buildings?

The aim of this paper is to explore this question by interviewing some engineering consultants on how they evaluate the performance of a building, and to what extent knowledge about building physics theory is being used during the design process to prevent moisture problems from occurring.

The driving forces behind this study are two research projects that are both looking at the use of building physics based design tools for engineering consultants in the building industry. By tools we mean any aid that influences the design. Tools can be either computer or paper based in the form of checklists, graphs, tables, simulations etc.

One project, *Performance indicators as a tool for decisions in the building process*, (Yverås 2003) deals with the problem of developing a design tool that will increase the application of building physics in the early stages of design. Performance indicators can assist in this decision-making and help to avoid failures that would otherwise reduce service life. Even though knowledge about designing a building is widely available, incorrect decisions are all-too common. Consequences from poor decisions can include a reduction in service life arising from conditions such as mould growth, rot and corrosion. These conditions can be avoided, but not without the application of robust knowledge based on the principles of building physics. However, this requires more than knowledge; it demands tools that designers can understand and use. It is important, therefore, to have a clear picture of what is required of any decision support tool, which is why the interview study is important in the further development of the performance indicator tool.

The second project, *Tools for determining the economical effects of building physics aspects during the building process*, (Burke 2003) investigates, studies and quantifies the economical benefits in using the knowledge from building physics as a design and decision tool in the building process. Problems in the building process related to building physics will be identified in co-operation with the building industry. Existing calculation programs, databases, statistical inquiries will be compiled into useful, easy to use tool packages especially designed to give adequate information about the costs and risks associated with different designs. These interviews were necessary to gain insight into what extent building physics is utilised in the building industry, and what types of applications designers want that would enable them to apply building physics theories more easily to designs.

2 Method

As mentioned in the background, the two projects behind this paper are developing design tools to be used during the design phase. Information and insight was needed about the design process in Sweden as well as the types of tools that designers would want to use. Since these tools are intended for designers during the design phase of a project, we focused our information gathering on designers who will potentially have use for our tools.

Of the various methods considered – for example experimental, literature review and surveys – the latter seemed to offer most promise. Due to the nature of our enquiry, we felt that an exploratory survey was more likely to reveal the key features of the underlying problem than either of the other methods.

Questionnaires were considered as the primary method for gathering information. However they have the disadvantage of being too linear. In addition, the information generated could not be anticipated, so it was not considered appropriate to gather the information by questionnaires. Interviews were more appropriate by allowing us to be dynamic, with the ability to probe interesting information to a much deeper level than is possible by questionnaires.

The questions for the interviews were formulated around two themes. One was to get a picture of the consultants’ conditions used to evaluate the performance of a building (i.e. their perception of the building process), and the second was to determine their level of comfort and experience in working with building physics issues.

To ensure that all interviews yielded comparable results, they were based on five principal questions with about 26 more specific questions. They consisted of open and closed questions that allowed us to assess various aspects of the interviewees unbeknownst to them. For example, a respondent can be assessed on his or her familiarity with the latest information and technology without directly asking. The closed questions allowed us to categorise the interviewees into predetermined categories. The five principal questions were:

1. How would you describe the design process of a building?
2. What are the most important performance requirements when designing a building?
3. How do you evaluate the performance of a building?
4. What influences do economical aspects, such as market conditions and market trends have on the design of a building?
5. Do you and your co-workers feel comfortable working with building physics issues, i.e. heat, air and moisture issues?

Interviews were conducted with eight building consultants over the span of two weeks and all consultants answered all of the questions. Two consultants declined to be interviewed because they were too busy but were positive to the interviews and recommended alternative people, whom accepted. All but one, the building physics professional, were chosen at random with no information about them prior to the interviews. It was decided to stop conducting interviews at eight because after the 5th or 6th interview very little new information was obtained.

The results were analysed based on the grounded theory approach, which "is a method for discovering theories, concepts, hypotheses, and propositions directly from data rather than from a priori assumptions, other research, or existing theoretical frameworks" (Taylor and Bogdan 1998, p. 137). In other words, there were no assumptions made as to what results we would obtain prior to the interviews.

3 Results and discussion

3.1 Relationships

Table 1 shows the profiles of the interviewees. Category refers to their general level of ability regarding the application of building physics to a design. Category A covers expert engineering consultants, category B covers the average ability expected from a building engineering consultant, and category C covers engineering consultants with very little ability. Some of the consultants indicated that experience is very important when dealing with the performance of a building. However, this was not apparent when analysing the interviews. Arfvidsson and Sikander (2002, p. 16) also found that consultants want more feedback on past projects, which supports our finding that they do not get adequate feedback on past projects, hence decreasing the value of experience. When looking at the experience level compared to the perceived level of awareness, i.e. the whole picture of the design process combined with a comprehension of complex performance issues and an awareness of the current levels of technology base, there did not appear to be any pattern. However, the level of education appeared to be related to their level of awareness. Figure 1 shows how we perceived the level of awareness for each person interviewed.

Table 1. *Profiles of those interviewed*

Category	Education hh	Experience
A	PhD in building physics	20 years
	Civil engineer + extra education building physics	15 years
B	Civil engineer	30 years
	Civil engineer	15 years
	Civil engineer	15 years
	Civil engineer	7 years
C	2-year engineering diploma	6 years
	High school	40 years

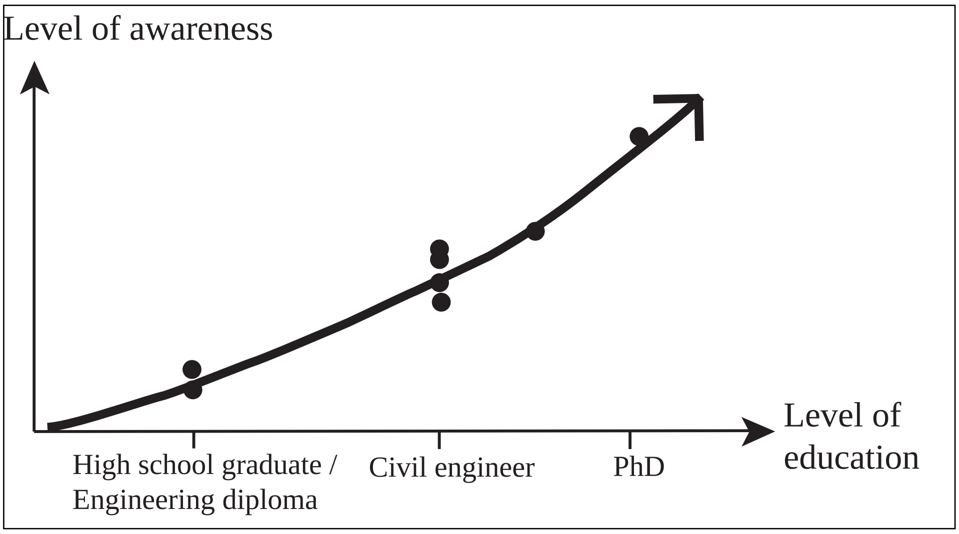

Figure 1. *Perceived correlation between level of education and awareness*

It is important to remember that the engineers in category C, and part of category B, did not have access to an expert. This could affect the results in this study since a lot of education flows internally from the experts in the companies. Other companies with experts and category C employees working together may have a totally different level of awareness due to the expert's influence. More in-depth studies would be needed to investigate this relationship further.

There also seemed to be different attitudes towards the required time directed to handle moisture control issues during design. Those within category A said that they would like to have more time whereas those in category C did not even allocate time especially for these issues. This was stated despite that they stated earlier that these issues are highly prioritised. They did however motivate it by using safe and well-known designs, referring to their own experience. However, their experience on well-known designs can be questioned as the consultants rarely have the time or the opportunity to return to, or follow-up projects that were finished 10 years ago or more. In practice, the long-term design for engineers is 2 years, according to one of the interviewed engineers.

When asked who is responsible for most of the performance problems experienced in buildings today, the consultants in categories A and part of B were also including themselves when asked. This was the opposite of the others (categories C and part of B), who blamed anyone else but themselves. These results partly agree with Arfvidsson and Sikander (2002, p. 13) who concluded that no actor in the building industry is willing to take responsibility for moisture prevention issues when designing a building.

Some of the questions dealt with how comfortable the consultant feels if they must work alone on problems dealing with building physics. In most cases the answer to this question was related to whether or not they have access to an expert in building physics. If the consultant had access to an expert, they were usually not comfortable working with these issues and usually sought advice from their expert before finalising a design. The consultants in this category acknowledged that since the media attention began, they have felt even less comfortable with these issues and rely heavily on their experts. Those without an expert in-house were more prone to saying that they felt very comfortable with building physics issues.

The group within the profession that has lower education level relies mainly on their experience. But if professionals rely mainly on experience, how do they know when there are gaps in their knowledge or whether some of their standard rules are no longer applicable (Barrett and Stanley 1999). Decisions made without knowledge of their consequences can have dire effect (Ellis and Mathews 2001).

One might easily draw the conclusion that people with less knowledge would suffer from insecurity more so than those with expert background. This was not the case during the interviews. Members of group C, showed a great deal of confidence and no worries about the complexity of building physics. Confidence is defined as the strength of a person's belief that a specific statement is the best or most accurate response (Peterson and Pitz 1988). In other words, it is a measure of how strongly they believe what they say. So far, no study has been performed that examines if there is any correlation between mistakes in design and the level of knowledge of the designer. However, there is a great deal of research, which indicates that people are often more confident than they are correct (Blanton *et al.* 2001). Blanton *et al.* (2001) states that educators may meet obstacles from people's overconfidence about their knowledge when trying to educate them. As the individual with the PhD said, "People *think* they can moisture proof a building, but they can't and I have to correct the problems later, which takes a lot of time."

3.2 Consultant/engineer and liability

Noting that moisture analysis requests began increasing after the media reported moisture problems, we began to wonder what the role of a consultant is in the Swedish construction industry and what their liabilities are. One tool used is called ABK 96 (Byggandets kontraktskommité 1996). It is a standard contract template that explains in detail how engineering and architectural consultants should conduct themselves. It also describes the limitations of liability that a consultant has. Most consultant companies use this voluntary contract to guide the consultants and also the client – consultant relationship. Each party is informed of what is expected of them by the other.

Despite this, there also appears to be some confusion around the labels of consultant and engineer for consulting companies, even though it is not spoken of. A consultant is defined as “an expert who gives advice.” (Princeton 1997a) An engineer is defined as “a person who uses scientific knowledge to solve practical problems.” (Princeton 1997b) Paragraph four (Byggandets kontraktskommité, 1996, p. 5) states that the consultant must be competent, professional and have adequate knowledge to consult in the areas of their field. However, overconfidence and lack of awareness in building physics on the part of some consultants, can cloud the issue of a consultant having adequate knowledge for building physics issues.

From the interviews, it was obvious that many consultants expect to be told what to do by the clients without informing the clients of what is available. In this way some of the consultants take on the role of engineer. This change in attitude is reflective of the traditional methods of building design consulting when a lot of information was unknown and the designs were simpler. An example was one consultant who disclosed technical solutions to example problems during the interviews that are proven to lead to mould and moisture problems in houses.

If a client is an experienced buyer or an expert client, they will have predetermined tasks and technical solutions available for the consultant since they are usually aware of all the major problems and their solutions. However, not all clients are fully informed, almost all have some weakness, for instance the science of building physics is not known by a typical client. A statement during one of the interviews, “Clients don’t know enough (about building physics-issues) to have any requirements” supports this idea.

There are occasions where poor decisions have been made that have lead to a failure in performance. This was exemplified during the interviews where one described how she strongly advised the client not to follow the architects’ direction of having the outside wall continue into the ground without a base. Two years later the predicted problems arose and the plaster closest to the ground fell off due to frost erosion. Clearly this was a case where the client was not used to handling these issues, lacked the experience to make a correct decision and the consultant failed to present the information. The reasons are considered to be due largely to the inability of design engineers to encode and present the consequences of a decision. By improving the quality of information during the design process, the client is better equipped to understand the different issues implicated in the project (Barrett and Stanley 1999). The consultant above admitted that by having real life cases to show, including a cost of the consequence, the outcome of this case might have been different.

The consultant in this case was not liable for the damages that incurred later because the consultant, firstly, recognised the problem and secondly, recorded their disagreement with the client in the protocol during the design phase. The consultant would have been liable for the damages if they did not inform the client of the problem, either voluntarily or unknowingly, i.e. was not aware of the consequences of a particular design feature. This case was not typical in that the consultant did a moisture analysis to determine the consequences.

The client usually assumes that the consultants they hired will solve all the known problems. The reality is that most engineering consultants, not all, are actually operating like engineering firms, in that they do not analyse a building from a building physical point of view unless asked specifically. Their reasoning being that changing the design requires more time, hence more money that clients are unwilling to pay. The result of this is that the minimum amount of work is done when analysing a building's design and the clients get very upset when problems occur.

One fact that they are neglecting to consider is that the cost of the building might actually decrease if the design is optimised using building physics. This could be in the way of material substitution, removing unnecessary components, or utilising a quicker construction method. In the U.K., quantity surveyors are able to calculate the cost difference of various designs. This position does not exist in Sweden so it is very difficult for engineering consultants to motivate changing the design based on building physics theory because of the difficulty in calculating the savings or extra costs associated with the changes.

3.3 Design tools

When asked what design tools were used when conducting the evaluation of a building from a building physics perspective, most replied that they did use some very basic ones. Two people, including the expert, built their own design tools from Delphi Pascal or Excel spreadsheets. Only the expert had a 'wish list' for what was desired in future tools. The others said they did not know since either their local expert uses the tools, or they did not use any.

When those who replied that they did not use any design tools were asked why, they replied that they were too costly to buy, too difficult to learn, required too much time to run the simulations, and not enough time was allocated to evaluate a building's design properly. These results follow Hien *et al.* (2000, p. 727) who found that "Most firms view the use of simulation tools as involving extra costs and effort but with little recognition and appreciation from the clients."

The most desired features of any computer-based tool, according to the consultants, were that they had to be easy to use in terms of low level of input and output data. These are statements that contradict with what is typically produced by researchers. Researchers have too often failed to deliver numerical models and tools that are user friendly and that take into account the education and expertise of the likely user (Goodings and Ketcham 2001). Hien *et al.* (2000) reveals that designers regard current tools as user unfriendly with very steep learning curves; moreover, the output generated could be extremely difficult to interpret and utilise for design decision-making. Ellis and Mathews (2001, p. 1011) also confirm this and have identified that tools of today are:

- complicated (not user friendly)
- time consuming (too much input)
- require a high level of theoretical knowledge (to make the input and to interpret the results)
- Information needed is not available during preliminary design.

Regarding the wish list of the tools the answers can be categorised after what level of education the respondents have. Those within category C had no wish list. Category B directed their interest to simplify computer programs in order to make use of such programs, whereas category A people had a bigger picture and directed the use of wish tools that could be used to persuade the clients for better performance. Examples of these are tools that can show the consequences of a chosen design in terms of reduced service life due to mould, rot or corrosion and cost analysis programs. Energy calculation, heat flow and airflow programs were not mentioned by any of the interviewees despite the fact that these topics all fall under the area of building physics.

Building industry related journals were also mentioned as being a tool that provides them with useful information. However, the interviewee did not state what specific types of journals they referred to.

In another civil engineering area, geotechnics, a trend is the growing number of experts (post doctoral) joining conventional firms instead of making a career within the university (Goodings and Ketcham 2001). This trend helps bring existing research into practice where it is most needed. Augenbroe (2002, p. 891) agrees with the idea of making more use of experts in the industry stating, “The latter trend recognizes that the irreplaceable knowledge of domain experts and their advanced tool sets is very hard to match by ‘in-house’ use of ‘dumbed down’ designer friendly variants”. This difference between having a design tool, versus having an expert in the company is significant, and this was reflected in the results of the interviews. All consultants who had access to an expert made use of them constantly, and all stated that they would be uncomfortable working with moisture control problems if they did not have access to their expert. They much prefer having the expert than using a simplified tool.

3.4 The bigger picture

Despite advances and knowledge in the construction industry in the past decades, it appears that this knowledge is not generally implemented until it becomes a requirement. This was explained by Becker (1999, p. 526) who states, "incorporation of new concepts into an existing professional activity field can be accomplished only if the right infra-structure, composed of some basic conditions, is present:

- the acting parties recognize the significance of these concepts and their contribution to improving the results of their work,
- clear routines and friendly working tools for smooth incorporation of the new concepts are available, and
- young new professionals are educated to regard the new concepts as an integral part of the profession."

These statements can be seen in the Swedish construction industry today. From the interviews, we saw that some recognise the significance of the concepts of building physics and building performance. Most indicated that there were no good design tools available for designing a performance building. Some did not even know that there were tools available on the market today.

With the third point, compliance and company tradition will quickly change the young professionals into operating like the other members of a company. Even if they want to make changes according to what was learned in school, a higher power can quickly overrule any decisions that they feel are unnecessary. The younger workers learn quickly not to make these decisions again in the future.

4 Conclusions

The interviews conducted with the engineering consultants in the Swedish construction industry suggest that experience might not necessarily be important when it comes to consultants and the topic of building physics performance. In addition, the higher educated consultants felt less comfortable and showed less confidence when working with these issues than their less educated counterparts. Their comfort and confidence levels were also inversely related to their amount of access to an expert in building physics, i.e. the more access they had, the less confident they were in working with these issues. The consultants with no expert support felt very confident and comfortable in working with these issues, however the quality of their work could be questionable due to a lack of feedback loops in the system. Awareness, education, and a view of the bigger picture are all needed to effectively deal with performance problems in the current construction industry. However, even if they possess all of these traits, there are many obstacles out of their control that can prevent an effective analysis of a building's design. Some of these obstacles include having to make do with the amount of time allocated to the analysis phase of a building, meeting the client's demands, the architect's demands, the level of competence of the consultant, whether or not they have access to an expert in building physics, and the types of tools they have at their disposal.

The interviews indicate that problems are still occurring in new buildings today because either clients do not request the correct design options, the designers do not include these options in their designs due to the extra time it takes, or the constructors disregard some basic issues which lead to problems during the construction phase. Sometimes clients do not request extra design work because they believe it increases the total cost and they will not be personally affected by the improvements, for example clients who build public housing, or apartments.

Further research is needed to determine if there is a relationship between the level of education and the level of awareness in building engineering consultants and the effect that their confidence levels have on clients.

Acknowledgements

The authors would like to thank the funding bodies for these projects, FORMAS (The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning), SSF (Swedish Foundation for Strategic Research), SBUF (Development Fund of the Swedish Construction Industry), Competitive Building, Lund Institute of Technology and JM AB. We would also like to thank all the consultants who gave their time and experience to us and all the people who have given us feedback for the improvement of this work.

References

Arfvidsson, J. and Sikander, E. (2002). Fuktsäkert byggande – Enkätstudie om kunskapsläget (Moisture-safe building – Survey of the level of knowledge) Gothenburg: FoU-Väst Report # 0205.

Augenbroe, G. (2002). Trends in building simulation. Building and Environment 37, p. 891.

Barrett, P. and Stanley, C. (1999). Better construction briefing. Oxford: Blackwell Science.

Becker, R. (1999). Research and development needs for better implementation of the performance concept in building. Automation in Construction 8, p. 525-532.

Blanton H., Carvallo M., DeHart T. and Pelham B. W. (2001). Overconfidence as Dissonance Reduction. Journal of Experimental Social Psychology 37, p. 373-385.

Burke, S. (2003). Reducing the Risk of Failure in Performance within Buildings In: ed. Atkin, B., Borgbrant, J. & Josephson, P.-E., Construction Process Improvement, p. 82-92, Oxford: Blackwell Science.

Byggandets kontraktskommité. (1996). Allmänna bestämmelser för konsultuppdrag inom arkitekt- och ingenjörsverksamhet av år 1996: ABK 96 (General rules for the consulting profession within architectural and engineering fields from 1996: ABK 96.), Stockholm: FörlagETT, p. 4-10.

Ellis, M.W. and Mathews, E.H. (2001). A new simplified thermal design tool for architects. Building and environment 36(9), p. 1009-1021.

Goodings, D.J. and Ketcham, S. A. (2001). Research versus practice in transportation geotechnics: Can we bridge the chasm? Journal of professional issues in engineering education and practice 128(1), p. 26-31.

Hagentoft, C.-E. (2001). Introduction to Building Physics. Lund: Studentlitteratur.

Hien, W.N., Pho, L.K. and Feriadi, H. (2000). The use of performance-based simulation tools for building design and evaluation - a Singapore perspective. Building and Environment 35, p. 709-736.

Jelvefors, A. (2002). Lägenheter vattenskadade på Bo01 (Waterdamaged apartment at Bo01). In Metro, Malmö.

Luthander, P. (2001). Skanskas byggslarv orsakade mögel (Skanska'sconstruction carelessness caused mould), Dagens Nyheter, Stockholm.

Peterson, D. K., and Pitz, G. F. (1988). Confidence, uncertainty, and the use of information. Journal of Experimental Psychology: Learning, Memory, and Cognition 14, p. 85–92.

Princeton University, (1997a). Wordnet 1.6 as found at http://www.dictionary.com/search?q=consultant accessed April 24, 2002.

Princeton University, (1997b). Wordnet 1.6 as found at http://www.dictionary.com/search?q=engineer accessed April 24, 2002.

Samuelson, I. and Wånggren, B. (2002). Fukt och mögelskador Hammarby Sjöstad (Moisture and mould damage Hammarby Sjöstad). Borås: Swedish National Testing and Research Institute.

Taylor, S.J. and Bogdan, R. (1998). Introduction to Qualitative Research Methods - A Guidebook and Resource. 3rd Edition, New York: John Wiley & Sons, Inc. p. 87-116.

Yverås, V. (2003). Performance Indicators as a Tool for Decisions in the Construction Process In: ed. Atkin, B., Borgbrant, J. & Josephson, P.-E., Construction Process Improvement, p. 68-81, Oxford: Blackwell Science.