Understanding the Mechanisms behind Fragmentation in the Housing Construction and Retrofit

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Abstract:

Housing and energy-efficiency policies often cause unintended consequences in the built-environment and beyond it, and encounter resistance by the potential users. Systems thinking and an integrated approach are suggested both for research and decision-making in order to avoid such unintended consequences and policy resistance. However, previous studies revealed that such an integrated decision making takes place neither at the policy nor at the industry level, and the resulting fragmented processes lead to performance gaps in the housing sector. This study investigates the mechanisms behind fragmentation based on a large set of stakeholder interviews conducted for the housing sector in the UK. For this purpose, the information obtained from these interviews is transformed into a system dynamics model. The model focuses on the improvement of housing performance by immediate actions such as resource allocation or by longer-term actions such as competence development both at the policy and industry level. Future research will focus on extending the model to the user level and elaborating it in participatory sessions.

Keywords: Housing, energy-efficiency, system dynamics, fragmentation, policy resistance

1. Introduction

The housing sector is a focal point of climate change policies in the UK, with its 27 percent contribution to the total energy consumption (DECC 2015a) and 12 percent direct contribution (not via energy suppliers) to the greenhouse gas emissions (DECC 2016). Shrubsole et al. (2014) summarize these policies that aim at increasing the energy efficiency of the housing stock as well as decreasing the greenhouse gas emissions. Based on these policies, the residential sector is expected to contribute 40 and 30 per cent of the total energy savings in 2020 and 2030, respectively (DECC 2015b).

Despite high expectations, the energy efficiency policies often fail to deliver satisfactory outcomes mainly due to policy resistance and unintended consequences. Policy resistance is attributed not only to the slow adoption of these policies by the households (James 2012, Marchand, Koh, and Morris 2015, Weeks, Delalonde, and Preist 2015) but also to the design-performance gaps in the industry's practice (Oreszczyn and Lowe 2010, Killip, Fawcett, and Janda 2014, Zero Carbon Hub 2014). As for the unintended consequences, they arise in the built-environment as reduced indoor air quality, increased fuel poverty or increased CO_2 emissions due to the rebound effect (Davies and Oreszczyn 2012). However, these unintended consequences extend beyond the built-environment and make various impacts on economic, social and natural environments such as on population health, emotional wellbeing and community connection (Shrubsole et al. 2014). In order to avoid such unintended consequences, systems thinking and an integrated approach are suggested both for research and for decision-making (Davies and Oreszczyn 2012, Shrubsole et al. 2014).

Integrated decision-making refers to a multi-objective, multi-aspect, multi-stakeholder view, in the context of housing, energy and wellbeing as mentioned by Davies and Oreszczyn (2012) and Macmillan et al. (forthcoming), and in decision sciences in general (Grushka-Cockayne, Reyck, and Degraeve 2008). In contrast, the single-focus in decision-making by any actor can be considered as a form of fragmentation. A lack of coordination and collaboration between actors is also often stated as a form of fragmentation (Perotti and Kontopoulos 2002, Lienert, Schnetzer, and Ingold 2013). In this study, we use '*fragmentation'* as a term that refers to both of these aspects, namely the singularity in actors' views and the lack of coordination and collaboration. It is important to note that these two aspects are interrelated, where the latter often leads to the former.

A recent project at University College London (UCL) adopted a systemic approach to investigate the links between housing, energy and wellbeing, and to inform policymakers and stakeholders about these links and the long-term consequences of policies (Macmillan, Davies, and Bobrova 2014). The project uses a participatory approach, based on stakeholder interviews and workshops which are discussed in detail by Zimmermann et al. (2015) with a focus on how they led to a shared meaning and learning. The information obtained from the interviews and stakeholder workshops resulted in a qualitative system dynamics model which represents the complex relationships within and between seven themes. These themes are community connection, energy efficiency, fuel poverty, household crowding, housing affordability, land development, and indoor air pollution (Macmillan et al. forthcoming). The existing model captures the complexity of the system with these seven themes, it does not yet address the *fragmentation* aspect which results from uncoordinated actions of various actors, such as policymakers, the building industry, local authorities and users, and which leads to performance gaps and unintended consequences.

System dynamics have long been used to deal with complex problems in the housing sector starting with *Urban Dynamics* (Forrester 1969), and with problems related to the energy consumption of the housing stock. Regarding the housing sector, existing studies focus on urban development (Eskinasi, Rouwette, and Vennix 2009), competitiveness in the construction industry (Gilkinson and Dangerfield 2013), and the housing market dynamics (Eskinasi, Rouwette, and Vennix 2011, Özbaş, Özgün, and Barlas 2014). Regarding energy consumption, the diffusion of energy-efficiency measures in the housing stock (Blumberga et al. 2011, Yucel and Pruyt 2011, Mueller and Ulli-Beer 2012) and occupants consumption behavior (Armenia, Falsini, and Oliveri 2009, Papachristos 2015) are addressed with system dynamics models. However, the issues leading to, and resulting from, the actors' fragmented decision-making are not covered in these studies.

Given this lack of attention paid to fragmented decision making processes, this paper aims at investigating and understanding the causal mechanisms behind fragmentation in the housing, energy and wellbeing domain. With this purpose, we develop a system dynamics model based on the information collected from stakeholder interviews, and preliminary simulations of this model are used to derive insights about the structure-behavior relationships.

In the remainder of this paper, Section 2 explains the interview method that generated the information about the goals and actions of stakeholders, and how this information is analyzed to investigate the causal mechanisms behind fragmentation. Section 3 discusses the fragmentation concept in more detail with respect to the information obtained from the interviews, and describes the resulting model structure.

Section 4 presents and discusses the preliminary simulation outputs of this model. The paper ends with conclusions in Section 5.

2. Method of Data Collection

The specific focus on fragmentation and integration in the implementation of housing projects emerged from an issue elicitation session at a stakeholder workshop in November 2014. In January and February 2015 an author and another member of the research team analyzed the clusters that emerged from the participatory workshop session. Fragmentation at the local level stood out and we conducted 16 interviews with a group of interdisciplinary stakeholders from government departments, non-government organizations (NGOs), industry, academia and community groups between February and October 2015. The interviews generally lasted between one and two hours. The semi-structured interviews followed four leading questions about the role of the interviewees, the nature and mission of their organization, their organizational experience with fragmentation and integration at the local level, and the personal and organizational delivery framework, as shown in Table 1. We encouraged participants to tell about their lived experience with fragmentation and integration and followed up with questions why fragmentation or integration emerged in order not to have them report on generalities but on specific causal relationships instead.

Table 1: Interview guide

Interviewee What is your role in your organization and for how long have you done this?
Organization What is the nature of your organization/business? Does your organization have a mission statement? If yes, what is it?
Integration How does integration get enabled and constrained in the context of your organization? Can you tell me about your experience here?
Delivery framework, attention What makes you think you have done a good job? Can you formulate your framework to deliver what you want to deliver, given all the constraints you face? Do you follow specific steps or priorities?

The interview transcripts formed a rich textual data set about how the policy teams, the industry supply chain and individual organizations in this supply chain work, and how the users and communities, as well as the technical aspects of building performance relate to these organizational mechanisms. We analyzed this textual data following the coding method of Kim and Andersen (2012).

Table 2: Summary of Kim and Andersen's Coding Technique Adapted from (Kim and Andersen 2012)

Description of the process	Main tool	Input	Output
1. Discovering themes in the data	Open coding	Raw text data	Definition of problem and system boundary; selection of relevant data segments
2. Identifying variables and their causal relationships	Open coding; causal links	Data segments (each Segment=one argument+supporting rationales)	Coding charts
3. Transforming text into words-and-arrow diagrams	Causal links; causal maps	Coding charts	Simple words-and-arrow diagrams
4. Generalizing structural representations	Axial coding; causal maps	Simple words-and-arrow diagrams	Final causal map

5. Linking maps to the data source	Map/data ID numbers	Coding charts and final causal map	Data source reference table

Kim and Andersen (2012) propose a five-step coding process summarized in Table 2, starting with open coding to identify the themes in the data. The coding process continues with the identification of individual causal relationships, visualizing these relationships in words-and-arrow diagrams, generalizing and simplifying these diagrams (axial coding) and recording the links between the final causal map and the data source explicitly. Kim and Andersen (2012) argue that axial coding in Step 4 is necessary to compare and integrate several small causal structures that result from different variable names referring to the same concept, or from different resolution levels used in explanation by the interviewees. In this study, due to the large amount of data and time limitations, we opt to merge step 2 and 4. Namely, instead of recording a causal relationship at any instance that is mentioned in the source data and then generalizing and simplifying these relationships, we start with general variables and relationships between them. This approach requires more intense open coding to identify the general variables by combining different instances when the interviewees refer to them. In this process, we used the qualitative data analysis software NVivo (QSR International 2015). NVivo allows coding the data from various 'sources' into 'nodes', which refer to variable names in our case. The nodes can be reorganized in a hierarchical manner, shifted or renamed, and these functionalities help in reaching generic variables and relationships iteratively.

Figure 1 exemplifies this node-based coding for the variable *Competence of Designers*. The competence notion encompasses several factors such as the *variety of design teams* that causes information loss, experience of the designers obtained by *learning* over time and the *awareness of sustainability* issues to be considered in design. These factors are repeatedly mentioned by multiple interviewees (sources) with multiple references, and coded as the child nodes of *Competence of Designers*. Based on these factors, we use 'competence' as a general variable representing the instances in the interviews that refer to qualifications, experience, awareness etc. of the designers

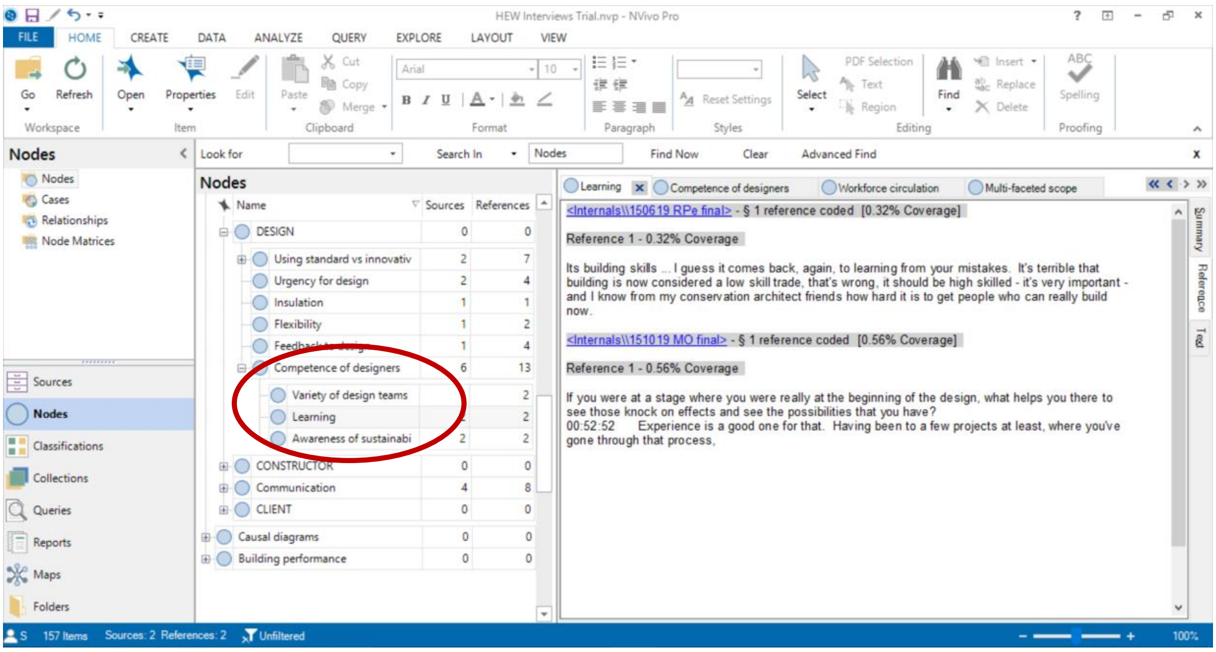

Figure 1: The NVivo screen showing the nodes related to workforce circulation

3. Model Description

This section firstly identifies the decision-making processes where fragmentation occurs in the context of housing, energy and wellbeing, and provides an overview of the main causal mechanisms. Then, the model segments that correspond to these processes are described with references to the stakeholder interviews.

The first step of the coding process, namely the open/thematic coding of the interviews have revealed that fragmentation is observed at three different levels. These levels are

(i) the policy level where policy measures are designed and implemented,
(ii) the industrial level where the construction and retrofitting industry works on the implementation of these policy measures, and
(iii) the user level where these policy measures, e.g. grants for energy efficiency retrofitting, are adopted and undesired consequences are experienced.

Besides these three groups, an important actor is the local authorities bridging policy, industry and community levels. Regarding especially the policy and industry level, two types of fragmentation can be distinguished: Inter-organizational and intra-organizational. Inter-organizational fragmentation refers to a lack of coordination between different organizations. It is exemplified by situations where policy designers do not take user requirements into account or construction companies do not comply with the design specifications set by the designers. As for the intra-organizational fragmentation, it refers to a lack of multi-objective, multi-stakeholder view within the organization due to the absence of multi-disciplinary staff, organizational learning from the mistakes, and coordination between different teams.

These issues that are considered as instances of fragmentation lead to *performance* gaps in the building site or neighborhood[1]. In this study, we use the term *performance* as an abstract aggregation of the building performance and the neighborhood performance. The building performance covers the energy-efficiency, carbon footprint, indoor air quality and comfort of the house, whereas the neighborhood performance covers the availability of third spaces in the neighborhood, available infrastructure, parking, etc. and the wellbeing of occupants related to those. The discrepancy between the actual performance of a site and the designed performance, or the discrepancy between the actual performance and the users' desired performance are the gaps that result from the actions of designers and constructors, and that lead to defects in the buildings or in the neighborhoods. Similar gaps are also observed at the policy level. The difference between the policy goals on the performance of a site and the actual performance indicates a performance gap in the policy design and implementation. Figure 2 depicts an overview of the model structure, which is based on these performance gaps represented by the variable *Discrepancy between Designed and Actual Performance* at the industry level, and *Discrepancy between Policymakers' Desired and Perceived Performance* at the policy level.

Either the industrial actors or policy makers could improve their performance as they observe performance gaps or failures. There are two mechanisms of improvement: *first order improvement* which refers to increasing the output or performance based on existing process and resources, and *second order improvement* which refers to an improvement based on a structural change in the process (Repenning and Sterman 2002). These improvement mechanisms are employed both at the policy and industry level, and they will be discussed in detail below.

[1] Third spaces

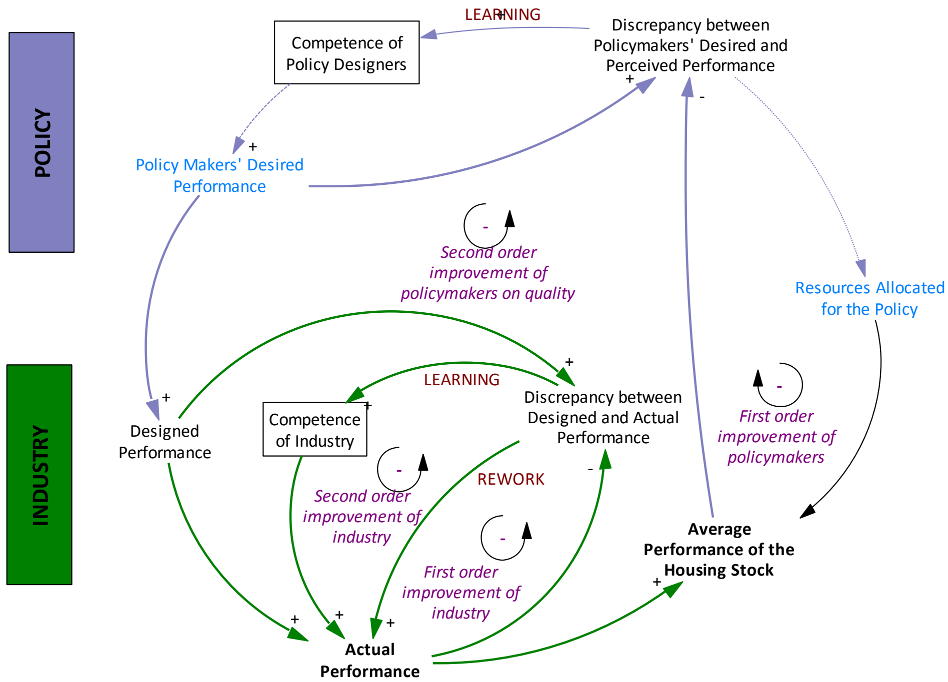

Figure 2: An overview of the fragmentation model

3.1. Policy

The loop *First order improvement of policymakers* in Figure 2 refers to the mechanism where they adapt the resources allocated for a policy as the discrepancy between their desired and actual performance increases. This adaptation has two dimensions as pointed out by our interviewees in the following statement, and divided into two loops shown in Figure 3.

> *"...when it becomes clear that projects aren't gonna make returns, they just shut them down, accept the losses and move on, whereas government can tend to keep trying because there are political considerations, or there are political reputations tied up."*

The first dimension refers to the *Scaling back* loop in Figure 3, where the resources are reduced as in the private sector if a policy does not return expected outcomes and the discrepancy between desired and perceived performance increases. However, as mentioned in the quote above, the public sector has a higher commitment to a project due to other factors such as political considerations, and the resources allocated for a policy can as well be increased as the discrepancy increases. This increase in resources stimulates the construction and retrofitting activities, and increases the *Average Performance of the Housing Stock*, which is the performance measure for policymakers.

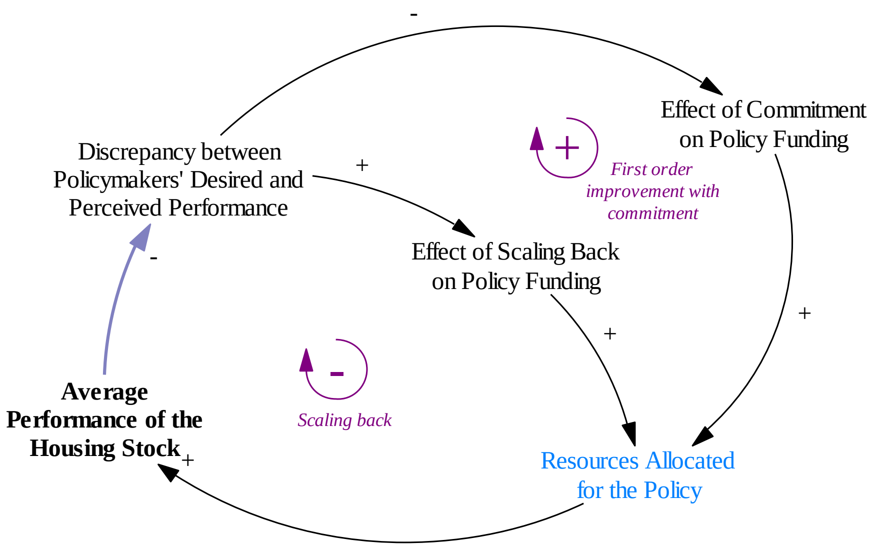

Figure 3: Allocation of policy resources as a first order response to performance gaps

The second order improvement by policymakers takes place as the competence of policy teams increases. As mentioned before, the competence variable refers to the ability of policy designers to take multiple objectives and multiple facets of a problem into account, in order to avoid unintended consequences and ensure that the discrepancy between desired and actual performance will be low. In other words, a high competence of the workforce in an organization helps in dealing with intra-organizational fragmentation and provides a better integrated decision making. Competence is developed primarily as the policy designers learn by the mistakes they make, and such a learning takes place if policy designers stay at a role for a long time, as one interviewee describes below:

> *"We, all of us, will make mistakes and the harder we try, the more mistakes we'll make, which is fine, as long as you don't keep making the same ones, but learn from them. So we have to stay around long enough to learn from our mistakes."*

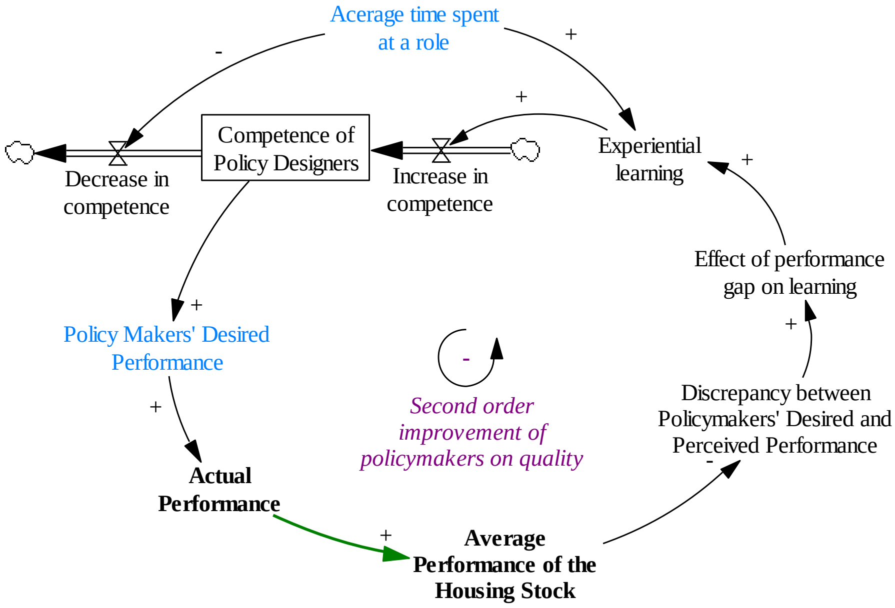

Figure 4: Second order improvement of policymakers with workforce competence

Therefore, we represent the *Competence of Policy Designers* by a stock variable since it accumulates over time as designers learn by their mistakes. *Experiential learning* is positively affected by the

Discrepancy Between the Desired and Perceived Performance which represents mistakes, as well as the *Average time spent at a role*. As increased competence positively affects the *Policy Makers' Desired Performance*, the second order improvement loop is closed as shown in Figure 4.

3.2. Industry

At the industry level, the first order improvement occurs as the constructors recognize the defects in the buildings and improve the performance through rework. Such defects are represented by the *Discrepancy between Designed and Actual Performance* in Figure 2. Similar to the policy designers' case, the second improvement occurs as the industry learns from these defects and increases its competence in creating higher performance.

The two important industry actors are 'designers' and 'constructors' whose decisions cause performance discrepancies if not made in an integrated way. The industry segment of Figure 2 can be broadened as in Figure 5, which depicts how these actors perceive and respond to performance discrepancies.

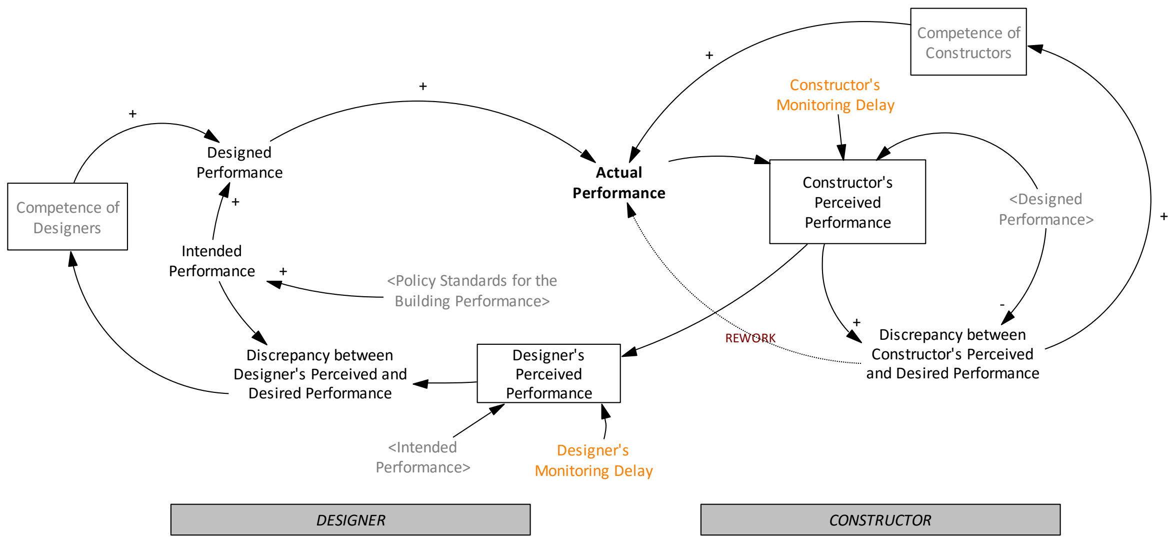

Figure 5: Industry's performance discrepancies

Regarding the constructors, they become aware of these performance discrepancies only when they actively monitor the outcome of their activities. Whether it is in the form of customer satisfaction surveys or formal measurements of physical aspects of the building, the stakeholders stated that, as exemplified by the quotes below, monitoring is not comprehensively conducted by the industry. Even if some of the projects are monitored, the results did not immediately lead to the perception of a performance gap.

> *"Yes, so there's a mixture of informal feedback and formal assessment, but at the strategic level, that's very difficult to track."*

> *"I don't know, we don't necessarily have the resource to necessarily follow up a significant number of clients, so when someone thanks us, that's quite nice."*

> *"...but you have to assume, most people are satisfied and we do do customer satisfaction surveys on some of our projects [...] given the volume of clients that we deal with, we can't necessarily push for feedback on all of them."*

> *"...[a housing project] actually took us eight years to do and [a housing project], although it was quicker, that was still around about five years to do the full sort of look at the process and the measurement of performance, the monitoring, the long term monitoring and then the*

reporting and so on."

"When we did some of our early work in early 2000 which looked at what was actually happening on site and looked at performance and began to talk about the performance gap and how big it is, or can be, a lot of developers simply said we were wrong and that we'd only measured one or two, or three or four houses and that these were just one offs because we didn't have a random sample ... of course, one can never get a random sample, they're always on safe ground with that one, but we couldn't say that this was indicative of the whole of housing production."

This perception of the *Actual Performance* put in place by the constructors is formulated as an information delay yielding the *Constructor's Perceived Building Performance* in Figure 5. This structure implies that the constructors become more aware of the actual performance of the buildings as they monitor it more closely although they initially assume that the performance they put is equal to the design performance.

As mentioned before, the constructors respond to a discrepancy between the actual performance of a building and the design performance by rework. In the model, this is included as the link that closes the first order improvement loop of the industry. However, we hear from our stakeholders that the forces to improve performance are very low. Often, these buildings start to be used only once they are fully built, rendering changes difficult. For example, an interviewee reported the resistance to increase performance even though it is recognized:

"...Since then, there's been obviously more work, we've measured more houses, other people have measured services and so on that there is now, at long last perhaps since the zero carbon hub report last year, there's at least a broad recognition across the industry that there is a performance gap; the key question is how do we tackle the performance gap. So it's taken perhaps 15 years for the industry to recognize that they have a problem, but I still don't see much movement in trying to solve the problem."

The competence of constructors is an important factor in realizing the *Designed Performance*, namely bringing the *Actual Performance* close to the *Designed Performance* in the model. The statements below raise the difference between the designed and actual performance, and exemplify how it is dependent on the competence of the builders.

"...the process by which many of the design imperatives and the design intentions and so on are not communicated particularly well to site and then the process on site of actually putting these things together is very traditional, [...] that's actually quite a fragmented process."

"Its building skills ... I guess it comes back, again, to learning from your mistakes. It's terrible that building is now considered a low skill trade, that's wrong, it should be high skilled - it's very important - and I know from my conservation architect friends how hard it is to get people who can really build now. They don't understand what the bits are meant to do [...] then the result is very dysfunctional."

Regarding the designers, their activities do not involve first order improvement because once the design is approved, there is no rework done on it as stated by the first quote below. Also, the feedback the designers receive on their work is weaker than the feedback constructors receive, because they are not often contacted by the constructors about the outcomes of their design, as mentioned in the second quote below. Therefore, in the model the *Designer's Perceived Performance* is represented also as the output of an information delay of which input is the *Constructor's Perceived Performance*. Designers' learning, hence their competence, is stimulated by the discrepancy between their perceived performance and intended performance, which reflects the policy standards. As in the case of constructors, the

Competence of Designers determines the extent that they can realize the intended performance in the design they create.

> *"I think that's very common in building construction, that a design decision gets made and if it's not challenged early enough, it stays in the design because there's no way to reverse that once you are on the site pouring concrete and that sort of thing."*
>
> *"So the proposed changes are usually circulated in the whole design and construction team, but the response, probably you're only ever gonna have the time, or the budget to provide a qualitative response to that. We may have no involvement at that stage at all sometimes, particularly if it's a form of the contract, with a design and build contract where we've only taken a design up to a certain stage, to building tender (construction tender) and we might not be consulted again on that one."*

4. Preliminary Simulation Results

The model presented in the previous section is not complete, since it is intended to be iteratively developed and elaborated through group model building sessions with stakeholders. Still, in this section we present the simulation results of this preliminary model, in order to understand the structure-behavior relationships.

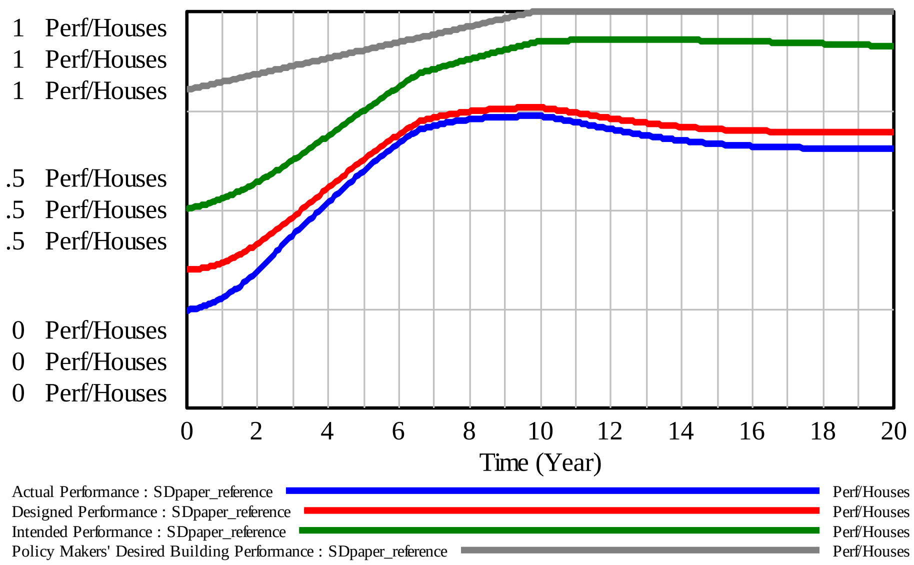

Figure 6: Dynamic behavior of Actual Performance (blue), Designed Performance (red), Intended Performance (green) and Policymakers' Desired Performance (grey)

Figure 6 demonstrates the behavior of three key variables in a 20-year simulation horizon. *Policymakers' Desired Performance* is formulated as a ramp function, implying that policymakers vision a 10 year period to achieve their desired performance, which is 1. *Intended Performance*, which represents what policy designers actually implement, increases over time although it is initially far below the desired level, following the increase in the desired performance and the increase in the competence of policy designers (Figure 7). The saturation in *Intended Performance* is attributed to a similar behavior in the competence of policy designers, which does not increase when the discrepancy between the desired and intended performance is low and learning does not take place. *Designed Performance* is far below the *Intended Performance*, ascribed to the low competence of designers shown in Figure 7. This low competence of designers is not only due to their shorter *average time spent at a role*, but also due to decreasing learning as the performance gap is closed. As for the *Actual Performance*, it closely follows the *Designed Performance*, mostly attributed to a high competence of constructors shown in Figure 7.

Still, closing the performance gap leads to a drop in the competence of constructors, which in return decreases the *Actual Performance* and widens the gap again.

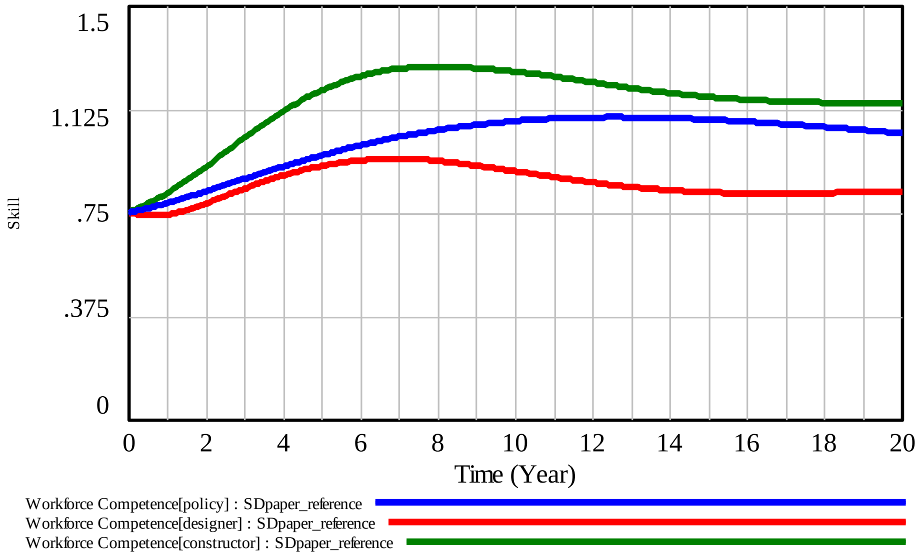

Figure 7: Dynamic behavior of Workforce Competence of the policy designers (blue), designers (red) and constructors (green)

5. Conclusion

This paper presented a model that represents the actions of policy makers, designers and constructors in the housing sector that result in fragmentation, and hence performance gaps. This model structure is derived from an analysis of the textual data collected from stakeholder interviews. The key reasons of performance gaps are identified as the lack of competence both at the policy and industry level, as well as the lack of monitoring activities.

In the future of this study, the boundaries of the model will be extended to cover the user level, i.e. the desired performance of occupants, how it affects the designed performance and the uptake of policy standards. Furthermore, the model will be elaborated in the group model building workshops in order to capture the most important aspects of the system and the underlying mechanisms in a participatory manner.

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