ENCONTRANDO UM ELO PERDIDO: ESTUDOS EM PRODUTIVIDADE NA CONSTRUÇÃO ENTRE OS ANOS 1940 A 1970 E NOVOS ESTUDOS NO CONTEXTO DA INDÚSTRIA 4.0

Rediscovering a Lost Link – Studies on Construction Productivity from the 1940s to the 1970s and New Data Collection Initiatives Through Industry 4.0

Luiz Fernando Mahlmann Heineck
Universidade Estadual do Ceará | Fortaleza, CE | luiz.heineck@uece.br

Fernanda Fernandes Marchiori
Universidade Federal de Santa Catarina | Florianópolis, SC | fernanda.marchiori@ufsc.br

João Paulo Maciel de Abreu
Universidade Federal de Santa Catarina | Florianópolis, SC | joaopaulojpma@hotmail.com

Madalena Osório Leite
Universidade de Fortaleza | Fortaleza, CE | madalenaosorioleite@unifor.br

RESUMO

Este estudo apresenta um comparativo de tópicos cobrindo aproximadamente trinta estudos em produtividade na construção conduzidos entre os anos 1940 a 1970, contrastados com um igual número de estudos nos últimos dez anos, onde já foram incorporados recursos da Indústria 4.0. A razão que justifica a iniciativa em revisitar tópicos que promovem profundo conhecimento no tema no passado e propor sua continuidade no presente. Isso promove um tributo aos autores mais antigos, que escreveram em honra aos pesquisadores-jurássicos. A maioria dos artigos mais antigos trabalhavam sobre largas bases de dados e era suportados por instituições estatais de pesquisa em locais como Grã-Bretanha, Irlanda, Suécia, Dinamarca, Países Baixos, França e Austrália. O método de pesquisa consistiu numa revisão bibliográfica narrativa, analisando comparativos quali-quantitativos entre temas, ferramentas de coleta de dados, apresentação de resultados e sua significância. Conclui-se que é possível reforçar os métodos de pesquisa mais do que meramente coletar dados estatisticamente sobre consumo de recursos na construção, reforçando a importância de técnicas como mapas de fluxo, diagramas de processo e diagramas de homem-máquina, que requerem grande volume de dados, mas não são acessíveis sem coletas automáticas de dados ou mesmo interpretações baseadas em inteligência artificial.

Palavras-chave: Produtividade; Revisão Bibliográfica Narrativa; Esforços de pesquisa no passado e no presente.

ABSTRACT

This study presents a comparative review of topics covered in approximately 30 studies on construction productivity conducted between the 1940s and 1970s, contrasted with an equal number of articles from the past 10 years, which already incorporate Industry 4.0 mechanisms. The rationale behind this initiative lies in revisiting topics that provided in-depth knowledge on the subject in the past and proposing the continuation of this research effort in the present. It also pays a tribute to older authors, that is, it is written in honor of Jurassic park researchers. Most of the older articles are characterized by large databases and were produced by state-funded research institutions in countries such as Great Britain, Ireland, Sweden, Denmark, the Netherlands, France, and Australia. The research method consists of a bibliographic review, supported by qualitative and quantitative comparisons regarding themes, data collection tools, presentation of results, and their significance. The study concludes that it is possible to reinforce the research on work methods rather than merely collecting statistical data on resource consumption in construction. It emphasizes techniques such as flowcharts, work process diagrams, and man-machine diagrams, which require extensive data but are now feasible due to automatic data collection and AI-based interpretation.

Keywords: Productivity; Literature Review; Past and Present Research Efforts.

1 INTRODUÇÃO

A forma com que ocorre a construção do conhecimento, incluindo métodos e formulação de raciocínios compete a estudos de Epistemologia (Monteiro, 2009). Dentro deles, são possíveis algumas abordagens para estudo de um domínio (recorte ou tema específico de conhecimento), tais como os estudos históricos, que não se restringem ao passado, mas servem como bússola-do-futuro (Pando, 2018).

Além desses estudos, outros mecanismos ajudam no avanço do conhecimento a partir do entendimento do passado, como ocorre no processo editorial de periódicos acadêmicos, ou por pesquisadores seniores, cuja bagagem direciona novos estudos, num processo de *gatekeeping* (Barzilai-Nahon, 2009). Existem, ainda, os *white papers*, que num contexto acadêmico, ou comercial e governamental, são construídos de modo a apresentarem tendências sobre um domínio (Silva; Novikoff, 2017).

Tal construção histórica, referente à produtividade na construção civil, foi apresentada em termos então atualizados há cerca de 35 anos atrás: em 1991, o Programa de Pós-graduação em Engenharia de Produção (PPGEP) da Universidade Federal de Santa Catarina produziu um relatório interno com 587 referências bibliográficas em língua estrangeira sobre a produção científica conhecida na área desde 1940, mais precisamente 1947, a partir dos esforços de centros de pesquisa europeus preocupados com a recuperação do ambiente construído da Europa, devastado pela Segunda Guerra Mundial (Heineck, 1991).

Esse relatório apresentou os principais autores, instituições, meios de divulgação e a organização dos tópicos em áreas ligadas aos fatores que afetam a produtividade (aprendizado, clima, ambiente econômico, etc.). Ele não está disponível em meios eletrônicos, assim como grande parte da bibliografia ali citada, que por ter sido elaborada pelos procedimentos antigos de impressão e editoração, e não ter passado por digitalização. Isso se confirma consultando a disponibilidade das publicações do principal órgão de pesquisa de interesse deste trabalho, o *Building Research Establishment* (BRE) da Inglaterra (antigo *Building Research Station*).

A literatura recente dos principais periódicos da área, e dos artigos do *International Group for Lean Construction* (IGLC), revisados desde o ano de 2004, não faz referência aos artigos que existiam naquele relatório. Por serem considerados relevantes pelos autores deste artigo, utiliza-se a seguinte estratégia para dar notícia dessas publicações antigas e propiciar o encadeamento de pesquisas unindo o passado e o presente, eventualmente apontando caminhos para o futuro: é feita uma crítica aos principais autores presentes no IGLC, mostrando o que poderiam ter citado em seus trabalhos, o que demonstraria a preocupação com ideias e técnicas seminais, e como a alusão a estas referências, na época clássicas ou episódicas, poderiam aprofundar as linhas de pesquisa em curso na atualidade, fazendo uma conexão do conhecimento entre épocas.

Para tal, inicialmente se discorre sobre a importância de obter, trazer à tona, discutir e incorporar conceitos que fazem parte do histórico da pesquisa sobre produtividade. Essa parte inicial do presente artigo realiza a contextualização. A revisão da literatura, em si, consiste no método de pesquisa, cujo objetivo foi de realizar um paralelo entre pesquisas recentes e dos anos 1940 a 1970, trazendo aspectos das pesquisas antigas que podem colaborar ao aprimoramento das pesquisas mais recentes. Ao longo deste artigo, identifica-se como o trabalho foi feito, suas limitações e recortes quanto a totalidade da bibliografia que é possível encontrar: o trabalho, assim, lista, comenta e compara o que foi produzido no passado - que constitui material de maior dificuldade para localização – porém ausente como referência em importantes trabalhos do presente, como os atuais trabalhos apresentados no IGLC.

1.1 MÉTODO

O método envolveu duas frentes de pesquisa. Na primeira, a listagem do PPGEP foi revisada, selecionando-se aqueles trabalhos que ainda eram considerados relevantes e que seriam de interesse para constituir uma biblioteca abrangente sobre produtividade na construção civil. Obteve-se uma listagem de cerca de trezentos artigos, todos listados na seção de referências. Como critérios para relevância, considerou-se a extensão do trabalho de campo, a respeitabilidade dos autores e suas instituições, a continuidade dos esforços de pesquisa em trabalhos sequenciais, correlações inovadoras entre os condicionantes do processo produtivo e sua produtividade, aplicações práticas de ferramentas, equipamentos e inovações em canteiro de obras e a senioridade do artigo.

Quanto mais antigo o trabalho, a partir do início da década de 1940, maior foi a pertinência para sua inclusão no portfólio bibliográfico, ainda que trabalho restrito, essencialmente prático e com poucas folhas. Os trabalhos listados necessariamente tratam de aplicações práticas, sendo excluídas simulações, otimizações, discussões teóricas e considerações subjetivas de variáveis associadas a produção e produtividade.

O portfólio bibliográfico exclui, com raras exceções as fontes em jornais científicos mais conhecidos, mormente os da *American Society of Civil Engineers* e o inglês *Construction Management and Economics*. Outros levantamentos específicos podem avaliar a importância dos artigos ali presentes, para as pesquisas atuais. O principal autor da área de produtividade, H. R. Thomas não é assim listado (no entanto, sua vasta produção científica a partir de 1980 é lembrada nos artigos mais recentes, graças a sua atividade acadêmica que perdurou até cerca de 2015. Também um livro de sua autoria, reunindo praticamente toda a sua produção científica, deixa disponível, de forma organizada, a sua contribuição para a área.

Especial cuidado foi tomado em relação às publicações do *International Council for Building Research and Documentation* (CIB) – Comite International du Batiment – por meio de sua *Working Commision W65 – Organisation and Management of Construction*. Os congressos gerais do CIB acontecem desde o final da década de 1950 e o primeiro congresso específico da Comissão W65 ocorreu em 1976, em Washington, USA, sucedendo-se os eventos trianuais desde Haifa (1978) até Sydney (1990), sendo esse último disponível quando da realização do levantamento do PPGEP (Heineck, 1991) citado supra. Considera-se que esse evento foi o principal desaguadouro das publicações na área de gerência da construção, dividindo sua importância com os eventos anuais do IGLC a partir de 1993 e com a proliferação de revistas científicas na área, abastecidas pela pressão juntos aos pesquisadores para que buscassem periódicos referenciados para sua produção científica, e não mais os simpósios da área.

A segunda frente de pesquisa foi a identificação na literatura atual de artigos específicos sobre produtividade ou que dependessem desta temática para operacionalizar seus modelos. Isso foi encontrado nas publicações do IGLC a partir de 2004, que tratavam de fluxos de maneira geral. Em particular, mostraram-se hegemônicos de forma crescente, pela quantidade de publicações, os trabalhos sobre programação por linha de balanço (*location-based management* (LBMS)), métodos e estudos de tempo na programação conhecida como planejamento *takt*, discussão geral sobre fluxos, continuidade e trabalho em progresso e, finalmente, medição e acompanhamento da produtividade em obra por meio do que se convencionou chamar de indústria 4.0.

Cabe salientar que o trabalho foi organizado da seguinte maneira: identificou-se uma temática ou a linha de pesquisa de um autor e a partir dessa foram escolhidas e comentadas na listagem geral de referências aquelas que poderiam ter contribuído para o artigo, ou que, em sua ausência, prejudicam a pesquisa hodierna, por não levarem em conta as dificuldades operacionais já sentidas no passado para implantar as propostas de novas ferramentas, técnicas e princípios no ambiente de obras.

2 ANÁLISE DO HISTÓRICO DAS PESQUISAS SOBRE PRODUTIVIDADE

O constante debate acerca da diminuição da produtividade na construção civil, ou sua taxa de crescimento menor do que a indústria em geral, é revisada em Borg e Song (2015), Sveikauskas *et al*. (2016) e Vogl e Abdel-Wahab (2015), cautelosamente comentando que, apesar de inúmeros trabalhos referenciados nesta perspectiva macroeconômica, pouco se pode afirmar. Os últimos autores sugerem utilizar a perspectiva de Costa *et al*. (2006) para fazer estudos nacionais e internacionais de *benchmarking* a partir de projetos reais, constituindo bancos de dados para avaliar, comparativamente o desempenho, em várias dimensões, das tipologias de edificação de cada país. Esta é a linha de trabalho da ONU (1953, 1959 e 1963), culminando com o trabalho sobre o efeito aprendizado em inúmeros países europeus. Pela sua extensão e riqueza de informações, esse é, a nível global, um ponto de partida para a constituição desses bancos de dados mundiais, por mais arrojada e complexa que seja essa proposta.

A existência de instituições de pesquisa especificas para a área de construção civil, criadas no pós-guerra e ativas até o desmonte das instituições públicas na onda liberalizante da economia da década de 1980, permitia a geração acerca do consumo de mão de obra e de materiais em vários tipos de obras e com várias tecnologias. Isso é exemplificado pelos trabalhos do BRE (1947, 1948, 1949 1950, 1953, 1954, 1958, 1960, 1962, 1965), ou pelos levantamentos do *Bureau of Labor Statistics* dos Estados Unidos (1970, 1971, 1974, 1975 e 1976). No Brasil, as Pesquisas Anuais da Indústria da Construção (PAICs), pelo seu caráter censitário para empresas de construção com mais de trinta operários, têm este potencial.

2.1 MURGUIA E A INTENSIDADE DO ESFORÇO PRODUTIVO

Murguia junto com seus pares Asmone, Brioso, Calmet, de Cossio, Middleton, Pimentel, Rathnayake, van Vuuren, Veran-Leigh, van Vuuren, e Urbina, ilustra uma evolução marcante em relação as aplicações de Construção Enxuta aos canteiros. Partem de aplicações corriqueiras de planejamento com linha de balanço e desenhos de mapas de fluxos de valor na realidade latino-americana, para aplicações mais recentes em canteiros de obras londrinos. Nos primeiros estudos, ainda prescritivamente, recomendam as aplicações usuais do planejamento para determinação de melhorias típicas, como manutenção de ritmos e precedências

em atividades em obra, ainda no âmbito do planejamento. Após, enfrentam aquilo que Alhava *et al*. (2019) colocam como a pequena possibilidade de sobrevivência das técnicas de planejamento em contato com a realidade de obras. Descontinuidade, precedências não planejadas, ritmos oscilantes e equipes com constituições variadas determinam a não aderência do real em relação ao planejado.

A pesquisa é realizada a partir da Universidade de Cambridge e em canteiros londrinos. A pequena distância se encontra a cidade de Watford, sede do antigo BRE, que pautou sua existência na tentativa de entender o que acontecia na realidade dos canteiros, a partir da documentação do chamado projeto *Finchampsteadt* (Forbes; Sterjnstedt, 1972) e Tindale *et al*. (s.d.). O desconhecimento dos vários artigos de Forbes e de Stevens, pesquisadores do BRE de cerca de 1958 a 1987, apontam para o aspecto caótico dos canteiros como só percebidos agora, em parte por levantamentos ainda manuais, mas que se propõe quanto a serem automatizados pelas possibilidades tecnológicas da Construção 4.0.

2.2 SACKS E A CONSTRUÇÃO 4.0

Sacks e seus pares, Bertelsen, Brodetskaia, Derin, Goldin, Harel, Haronian, Korb, Maraqa, Ma, Pitkäranta ,Partouch, Priven, Ribon,Savosnik, Sharoni, Spatari e Yeung representam a liderança entre os pesquisadores da comunidade da construção enxuta em termos de aplicações práticas relativas a indústria 4.0 em canteiros de obras. A partir dos resultados avaliados em canteiros reais, procuram simplificar o processo de pesquisa por modelagens, simulações e criação de métricas quando aos fluxos de trabalho, assim como criando condições contratuais (e de organização da indústria) para melhorias dos processos em obra.

Yeung *et al*. (2023) procuram recriar a tomada de decisão dos vários participantes do processo produtivo em termos de parâmetros operacionais como ritmos de produção, tamanho das equipes, número de equipes, uso dos dias ao longo do calendário (trabalhos em períodos como sábados), quantidade de equipamentos e sua disponibilidade em termos de manutenção, estoques de materiais, definição de pré-requisitos e sequências, zoneamento do trabalho, logística e mecanismos para solicitar materiais e equipamentos. Como acerto, a simulação oferecida consegue reproduzir a duração efetiva de um projeto, como se os agentes ao tomarem suas decisões em ambiente simulado, conseguissem chegar ao mesmo resultado que ocorreu na realidade. No entanto, para surpresa dos pesquisadores, a sequência, as precedências, a continuidade do trabalho a nível individual, das equipes de trabalho, não guardam similitude entre o real e o simulado. Esse descolamento é observado também nos trabalhos de Heineck, a partir de dados obtidos junto ao BRE.

Sacks e Harel (2007) introduzem incentivos financeiros na tentativa de estabilizar o comportamento errático de subempreiteiros em obras, atendendo múltiplos canteiros ao mesmo tempo, com frequentes entradas e saídas de cada um deles. A discussão sobre incentivos financeiros pode ser iniciada a partir do relatório do BRE de 1958 sobre essa forma de obtenção de aderência dos funcionários ao estipulado pela gerência.

Partouche *et al*. (2008) descrevem a construção do *Empire State Building*, no início da década de 1930, colocando-o como um exemplo da produção em massa, sem necessariamente encontrar princípios intuitivos da Produção Enxuta e, por conseguinte, da Construção Enxuta, filosofias ainda naquela época não formuladas. A discussão está alinhada com os estudos do BRE relativos a novas tecnologias e suas implicações no consumo de mão de obra, no uso de pré-fabricados e as dificuldades operacionais na mecanização dos canteiros, como em Bishop (1958, 1962a, 1962b, 1964, 1965), BRE (1948, 1949, 1960a, 1960b e 1965), Forbes e Cooper (1965) e Steward e Torrance (1978).

Em suas aplicações, os trabalhos de Sacks pressupõem a existência de dados de produtividade dentro das empresas de construção civil de Israel, sem que haja qualquer menção a essa disponibilidade, precisão e possibilidade de modelagem por fatores que a afetam.

2.3 SEPPÄNNEN E A REPETIÇÃO AO LONGO DOS LOCAIS DE OBRAS REPETITIVOS E NÃO REPETITIVOS

Seppännen e equipe (Aaltto Al Baraz, Berghede, Chauhan, Dave, Evinger, Frandson, Halttula, Heinonen, Kala, Kankainen, Kenley, Kujansuu, Lavikka, Lehtovaara, Modrich, Mouflard, Mustonen, Olivieri, Örmä, Pesonen, Peltokorpi, Peuronen Pikas, Rannisto, Riekki, Reinbold, Ronkainen, Ruohomähkt, Sahlberg, Salerto, Tetik, Viitane) resgatam a Linha de Balanço como técnica de programação de obras repetitivas, como apresentado em Lumsden (1968) e *National Building Agency* (NBA, 1968, 1970, 1971). Em princípio, segundo estes trabalhos anteriores, há necessidade de dados de produtividade para definir as equipes de trabalho em sua composição e equilibrar os ritmos de trabalho, pelo emprego de múltiplas equipes ou aumentando/diminuindo o número de profissionais/equipamentos em cada equipe. Não há menção, novamente, quanto à disponibilidade desses dados nas empresas em países do norte europeu. Bishop (1972), Clapp (1965, 1977,

1978), Forbes (1980), Lemessany e Clapp (1975, 1978) e Stevens (1984a, 1984b), mostram o esforço de pesquisa para obtê-los, para grande parte dos serviços em obra, pelas técnicas de medição empregadas pelo BRE, que culminaram com a criação de um pacote computacional baseado em observações instantâneas (Stevens, 1987). Em princípio, os Países Baixos teriam desenvolvido uma sistemática para coleta de dados de produtividade em obra por meio de uma empresa gerida por um consórcio de construtoras (Van den Graaf, 1979). Acredita-se que os dados de produtividade não sejam baseados em manuais disponíveis para a construção civil, objeto de críticas quando a sua atualização e credibilidade por autores como Chang (1990) e Fleming (1978).

2.4 TOMMELEIN E HAGHSHENO – GRAFICO BALANCEADO DE RECURSOS E O PLANEJAMENTO *TAKT*

Pelo lado americano, Tommelein e equipe (Bardaweel, Ba scoul, Coelho, Emdanat, Faloughi, Frandson, Linnik e Singh) utilizam o conceito do gráfico balanceado de recursos, herdado dos conceitos iniciais do Diagrama Homem-Máquina de Gilbreth (1909), para transferir para a construção civil o conceito de planejamento *Takt* da indústria manufatureira. Pelo lado alemão, Haghsheno e equipe (Binninger, Dlouhy, Oprach, Krichbaum, Müller, Schattmann e Steuer) também o fazem. Tommelein e Singh (2023) formalizam a possibilidade de aplicar o planejamento *takt* para áreas não repetitivas criando o conceito de densidade de trabalho presente em diferentes áreas de construção. Não há evidências quanto às origens dos dados de produtividade, tanto no caso americano quanto alemão. Sua variabilidade em vários níveis é conhecida de há muito, nos trabalhos de Bishop (1966, 1968), Forbes (1966, 1969, 1980b) e Forbes e Mayer (1968).

Beamish (1978) conduz o único estudo conhecido para tentar modelar a produtividade a partir de fatores que a afetam, utilizando uma grande massa de dados de canteiros ingleses, mas ainda com resultados com baixa precisão dos modelos de estimativas, tanto para extrapolar os dados para a amostras ou a população de produtividades esperadas para um mesmo serviço. Pigott (1972) se constitui no único trabalho conhecido, a partir de coleta de dados em canteiros, para tentar avaliar a produtividade em equipes de diferentes constituições em termos de profissionais e serventes. Ademais, introduz o conceito do número de visitas em excesso para terminar um serviço, que vai terminar sendo uma métrica para o acompanhamento das falhas de um planejamento *takt*, onde, em princípio, haveria concentração de esforços e apenas uma visita para terminar cada local de trabalho.

O rigor em que os tempos *takts* terminam é impactado por um possível excesso de capacidade para equilibrar as várias frentes de trabalho e permitir que cada atividade seja terminada a termo, mesmo diante das variabilidades típicas da produtividade da mão de obra. Por outro lado, o espalhamento das equipes, o aumento do trabalho em progresso, o uso das folgas imanentes aos próprios tempos produtivos, assim como o rearranjo de tempos auxiliares e improdutivos são imperativos para, em um primeiro momento, operacionalizar o planejamento *takt*, e conquistar os operários para gradativamente organizarem seu trabalho e seus deslocamentos segundo preceitos de racionalidade.

2.5 KALSAAS E WANDAHL E A QUESTÃO DOS TEMPOS PRODUTIVOS, AUXILIARES E IMPRODUTIVOS

Os países nórdicos apresentam representantes que em nome de estudar e conceituar fluxos na construção utilizam os conceitos de tempos produtivos, improdutivos e auxiliares na construção, não fazendo menção aos trabalhos iniciais de Duff (1979), Peer e North (1971) e Verschuren (1980). Em geral, é utilizada a técnica da amostragem do trabalho para fazer esses levantamentos. Na Dinamarca se encontra a equipe de Wandhal (Arilden, Ergul, Gross, Hansen, Johansen, Lerche, Loyola, Madushanka, Neve, Nielse, Nissen, Pedersen, Pérez, Salling). Na Finlândia e contando com aplicações também na Noruega se tem a equipe de Kalsass (Aslesen, Berge, Bolviken, Drevland, Finsádal, Fosse, Grepperud, Grindheim, Gundersen, Hasle, Hinlo, Jensen Laeknes Lia, Ringerike, Skaar e Thorstensen).

A técnica da amostragem do trabalho (ou observações instantâneas) é aplicada ainda com softwares desenvolvidos artesanalmente. Contudo, há muito já está disponível no Building Research Establishment Site Activity Analysis Package (BRESAAP) conforme Stevens (1987) representa o coroamento de todo o desenvolvimento deste órgão, desde 1947 na medição de produtividade no canteiro. Tem como um de suas possibilidades a medição destes tempos produtivos, auxiliares e improdutivos a qualquer nível de detalhe que se julgar conveniente (serviço, sub-serviço, local, operário, local, data, hora e operário). Em verdade, o uso do BRESAAP para medição desta distribuição de tempos representa uma subutilização de seu potencial: permite também avaliar consumo de mão de obra pelas várias atividades, suas durações e localização do trabalho ao longo do processo produtivo de uma obra (Heineck, 1982).

3 CONCLUSÃO

O contraponto oferecido neste trabalho entre a produção científica de vários autores recentes e a bibliografia antiga que se sabe existir e que poderia subsidiar seus trabalhos mostra que se apresenta como novidade hoje ou que se ignora as dificuldades já apontadas anteriormente sobre o desnecessário grande trabalho de processo em obra, a variabilidade associada à medição de produtividade, as dificuldades de sua modelagem com estatística levando em conta um conjunto amplo de fatores que afetam a produtividade, a necessidade de parâmetros para sequenciar e engrenar os ritmos das várias atividades, a criação de tempos *takt* a partir de gráficos balanceados de recursos que minimizem o excesso de capacidade de trabalho que permita sua efetividade e o uso ainda parcial das potencialidades da técnica de observações instantâneas.

Da mesma maneira, a integração da perspectivas de obtenção de dados detalhados a partir das tecnologias e características específicas de cada obra, em seu local de execução, e diante de culturas construtivas próprias com a perspectiva mais abrangente que permita a formulação de políticas públicas para o equacionamento dos custos, existência de mão de obra e prazos de projeto a nível macro pode retomar experiências que já foram empregadas em momentos de dirigismo governamental na busca de resolver problemas de construção/reconstrução do ambiente construído de países que viram seu estoque de edificações não acompanhar as necessidades da população.

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